The Structure and Origin of the Swan Band Spectrum of Carbon

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V. *The Structure and Origin of the Swan Band Spectrum of Carbon.*

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[PLATE 4.]

CONTENTS.

I. *Historical Introduction.*

Since its discovery by W. SWAN almost exactly seventy years ago, speculations as to the origin of this familiar band spectrum have been prolific in spectroscopic literature. A good summary of these opinions and the experimental data upon which they were founded is given by WATTS (1), writing in 1914. With the exception of one or two writers, the two opposing schools have favoured a Carbon molecule and a Hydrocarbon molecule, respectively. The latter school have for the most part specified in particular an acetylene molecule. Thus among a vast number of experimenters VAN DER WILLIGEN (1859), ATTFIELD (1862–1875), DIBBITS (1864), MORREN (1865), PLUCKER and HITTORF (1865), HUGGINS (1868), WÜLLNER (1872), SALET (1873), SECCHI (1873), CIAMICIAN (1880), DESLANDRES (1888), and EDER (1890), favoured a carbon molecule (presumably C_2). On the other hand SWAN (1856), ÅNGSTRÖM and THALEN (1875), LIVEING and DEWAR (1880), and many others favoured a hydrocarbon. The latter writers conducted a great deal of careful research (2) on the flames of Carbon compounds, the vacuum tube spectra of Carbon gases, and the Carbon arc in various gases, and they affirm that the emitter is an acetylene molecule, since this gas can be withdrawn from the flames of

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burning hydrocarbons which show the bands well. In the light of our present knowledge one or two comments are suggested as we review all this work. It is clear that in the vast quantity of experimental work of the former school the extraordinary difficulty of ensuring the complete absence of Hydrogen—either occluded in the carbons or present as water vapour—was not appreciated. We have, for example, a similar and comparatively recent controversy (3) with reference to the origin of the Nitrogen afterglow, in which the degree of freedom from Oxygen of a sample of Nitrogen was the point at issue.

Another very natural idea which prevailed until recently was that the emitters of band spectra were necessarily molecules known to chemistry, the most stable ones being those most likely to radiate under discharge conditions. Our present views are almost the reverse of these, and it seems probable that polar molecules cannot radiate band spectra at all. An excellent paper representative of these views has recently been published by MULLIKEN (4)—" On a class of one-valence electron emitters." The old ideas, therefore, which led to the choice of an acetylene molecule as the radiator of the Swan bands were certainly ill-founded, but by a coincidence it happens that a C_2H_2 molecule must now be quite definitely accepted as their emitter. The present paper contains the evidence for this statement. Hitherto measurements of the fine structure of only three heads have been available, and these from photographs take under arc conditions. It has been found desirable to make a complete re-measurement of the fine structure of these and other heads under new low temperature conditions of production. Some 2,000 lines are tabulated. A considerable number of these have been given series assignment, and the modern quantum theory of band spectra in its various aspects has been applied to the data. The scope of the resulting analysis may be gauged from the table of contents.

II. *Production of the Swan band spectrum.*

A large variety of conditions and methods yield this spectrum, many of which are of some experimental interest, and it is thought desirable to tabulate some of them :—

(1) Flames. Most flames containing burning hydrocarbons, in particular the ordinary Bunsen flame.

(2) The Carbon arc in Hydrogen (1–10 mm. gives best results), also the Carbon arc in most imperfectly dried gases.

(3) Vacuum tubes containing low pressure Carbon gases (together with a trace of Hydrogen), especially when a condensed discharge is used.

(4) A spark between poles of Carbon in Hydrogen. The Swan bands increase in brilliance up to a gas pressure of about 10 atmospheres.

(5) The Carbon arc under water and other liquids—*e.g.*, glycerine and pure hydrocarbons.

(6) The uncondensed spark in alcohol, glycerine, etc.

(7) Vacuum tubes containing traces of Carbon gases, and filled with 20–50 mm. of one of the inert gases.

The sources of the spectrum used by the writer were (2) and (7). The Carbon arc burning in a stream of Hydrogen at a low pressure yields the bands brilliantly, and this method was used to photograph the 5165 and 4737 bands. It presents a certain characteristic development of the structure which will be discussed later. The greater part of the experimental work was done with a tube of the " H " pattern, having a capillary about 20 cm. long and 1 mm. diameter, and fitted with Carbon electrodes, side bulbs containing KOH and P_2O_5, and a Palladium regulator. This was filled with pure Argon at about 30 mm. pressure, and the tube was excited by an A.C. generator supplying a high tension transformer having an output of 500 watts at 10,000 volts from the secondary. When the tube is in the right condition this yields a green light of exceptional brilliance, of which the spectrum is that of the Swan bands and the 4315 CH bands. This production of the Swan bands with great brilliance in high pressure Argon is of considerable interest both in itself and in the evidence it affords of the emitter of these bands (5). If the tube is excited by a mild discharge for a considerable time with the regulator heated so as to remove all Hydrogen, a stage is ultimately reached when the tube " cleans up," and only the continuous spectrum of high pressure Argon and a few lines of the red line spectrum are visible. If Hydrogen is then admitted through the regulator the Swan bands at once re-appear with great brilliance, continual introduction of Hydrogen eventually replacing them by the " Triplet System" (6). This points strongly to some hydrocarbon molecule as the emitter of the Swan bands, and to a hydrocarbon molecule of greater Hydrogen content as emitter of the " Triplet system." These processes are all reversible by removal of the Hydrogen. Similar effects are obtained if, instead of admitting H_2, a small bulb containing $KMnO_4$ is attached to the tube and gently heated to introduce a little Oxygen. Both the Swan bands *and the Triplet system* can be produced, which only serves to indicate the production of a certain amount of Hydrogen in this case also.

III. *Tabulation of the Data.*

Photographs of excellent quality were obtained of the sequences λ 4380, λ 4737, λ 5165, and λ 5635 in the second order of a 21-foot concave grating having a dispersion of 1·3 Å per mm. The 6191 sequence in the orange was photographed satisfactorily in the first order, as was also the 6857 sequence, with sufficient strength to yield measurements of most of the heads. Wellington anti-screen plates were used in the blue region, and Ilford extra-rapid panchromatic plates for the rest of the spectrum, excepting the λ 5635 group, which was photographed on Marion iso-record plates. Tables I, II, III and IV give detail of all the fine structure of the λλ 5165, 4737, 5635 and 6191 groups observed on these plates, together with the additional structure in the case of the λλ 5165 and 4737 bands obtained from arc photographs. The heads only have been measured in the 4380 " group of three," and in the red group. There is no doubt that the former group constitutes a part of the Swan spectrum, representing, in fact, the vibrational transitions (2, 0), (3, 1), and (4, 2); but the complexity of its fine structure, which appears different from that of the other bands, will necessitate a third or fourth order photograph before it can be analysed. The quality of the definition obtained makes it probable that the relative values of the wave-lengths recorded in Tables I, II and III may be relied on to about 0·002 Å.U., and those of Table IV to about 0·005 Å.U. The absolute values were obtained from measurements of a number of plates, and are probably correct to 0·01 Å.U., excepting for the heads of the red group, for which the error may average 0·02 Å.U. Tables V and VI give the wave-lengths of the heads of the violet and the red groups.

The only other fine structure measurements of Swan bands are those by Komp (7) of the 5635 head, Hindrichs (8) of the 4737 head, and Leinen (9) of the 5165 head, the data of which were presumably obtained from arc photographs. As already mentioned, the fine structure of the bands is in this case strikingly different in appearance from that of vacuum tube production—the former produces, in fact, a high temperature and the latter a characteristically low temperature distribution of energy among the rotational states. The difference in appearance, together with other peculiarities, originally suggested to the writer that two distinct systems were involved in each band, each consisting of a P and an R branch. These were called the "Tail" system and the "Head" system, and were investigated extensively as such (*vide* Section V). There are no Q branches present. Under arc conditions the fine structure of both systems is remarkably developed—*e.g.*, in the 5165 head (see Plate 4 Nos. 4 and 5) the "Head" triplets, which almost fade out at 10 or 12 Å.U. from the head, are developed in the arc to at least 120 Å.U. Long exposures would probably make it possible to double this extension. On the other hand, the "Tail" triplets—which are a very conspicuous feature in the tube photographs, being developed from about the point where the "Head" system fades away—are comparatively faint in the arc until we proceed much further outwards; but the subsequent development is very prolonged. These features are clearly seen in the 5165 band, since the intensity falls off rapidly in the $\Delta n = 0$ sequence, and therefore the succeeding heads at λλ 5129, 5097, etc., do not obscure the effect.

Subsequently it was found that the idea of two systems was untenable, and the so-called "Tail" system is to be regarded as an R branch, the "Head" system being a P branch.

In the Tables subscripts 1, 2 and 3 are used to denote the less refrangible, the middle and the more refrangible members of a triplet. The successive band heads of the same group are differentiated by accents—*e.g.*, in the group corresponding to $\Delta n = 0$, $P(m)$, $R(m)$ apply to the (0, 0) band; $P'(m)$, $R'(m)$ to the (1, 1) band; $P''(m)$, $R''(m)$ to the (2, 2) band, etc.

IV. *Evaluation of the Rotational Energy Functions.*

As the succeeding analysis of the fine structure data depends upon this evaluation, the details of the method will be presented here. A slight departure from the usual procedure has been adopted, and formulæ have been developed which, it is thought, present some advantages.

If F and f are used for the initial and final rotational functions, then typical lines in the positive and negative branches of a band which results from the vibrational transition $(n' \rightarrow n'')$ are given by

$$\left.\begin{aligned} R(j) &= F(n', j-\varepsilon+1) - f(n'', j-\varepsilon) \\ P(j) &= F(n', j-\varepsilon) - f(n'', j-\varepsilon+1) \end{aligned}\right\} \quad . \quad . \quad . \quad (1)$$

where j is a quantum number assumed always integral and characterising the total angular momentum of the molecule. $j = m + \varepsilon$, where m = angular momentum of the nuclei, and ε = component of electronic angular momentum about the axis of rotation (usually it is close to $\frac{1}{2}$). Rotational transitions are characterised by $\Delta j = \pm 1, 0$, but not necessarily by $\Delta m = \pm 1, 0$, since ε may change slightly in the transition. From equations (1) it follows that

$$\left.\begin{aligned} R(j+1) - P(j) &= F(n', j-\varepsilon+2) - F(n', j-\varepsilon) \\ R(j) - P(j+1) &= f(n'', j-\varepsilon+2) - f(n'', j-\varepsilon) \end{aligned}\right\} \quad . \quad . \quad . \quad (2)$$

which are the two combination principles to be satisfied by bands having the same initial and the same final vibrational quantum numbers respectively. From equations (2) we can also determine separately the forms of the initial and final rotational energy functions.

Having located the origins of the various bands, which should be such as to satisfy these combination principles, the assignment of rotational quantum numbers can be made, giving the values $j = 1$ to the lines on either side of the origin (so that they correspond to transitions of j from $2 \rightarrow 1$ and $1 \rightarrow 2$). This usually means transitions of "m" approximating to $1\frac{1}{2} \rightarrow \frac{1}{2}$ and $\frac{1}{2} \rightarrow 1\frac{1}{2}$, though not necessarily exactly this.

Forming the quantities $R(j+1) - P(j)$, $(= \nu'$ say), for all the observed values of j, we then obtain a formula to fit them. In the following work we assumed

$$\nu' = \alpha + \beta j + \gamma j^2 + \delta j^3 \quad . \quad . \quad . \quad (3)$$

and obtained the values of α, β, γ and δ by the method of least squares. This involves solving the four normal equations :—

$$\left.\begin{aligned} \Sigma \nu' &= \Sigma\alpha + \beta\Sigma j + \gamma\Sigma j^2 + \delta\Sigma j^3 \\ \Sigma j\nu' &= \alpha\Sigma j + \beta\Sigma j^2 + \gamma\Sigma j^3 + \delta\Sigma j^4 \\ \Sigma j^2\nu' &= \alpha\Sigma j^2 + \beta\Sigma j^3 + \gamma\Sigma j^4 + \delta\Sigma j^5 \\ \Sigma j^3\nu' &= \alpha\Sigma j^3 + \beta\Sigma j^4 + \gamma\Sigma j^5 + \delta\Sigma j^6 \end{aligned}\right\} \quad . \quad . \quad . \quad (4)$$

The evaluation of these is facilitated by using formulæ for the sums of the powers of the natural numbers, viz.—

$$\sum_1^j j = \frac{j(j+1)}{2}, \qquad \sum_1^j j^2 = \frac{j(j+1)(2j+1)}{6}, \qquad \sum_1^j j^3 = \left[\frac{j(j+1)}{2}\right]^2$$

$$\sum_1^j j^4 = \frac{j(j+1)(2j+1)(3j^2+3j-1)}{30}, \qquad \sum_1^j j^5 = \frac{j^2(j+1)^2(2j^2+2j-1)}{12},$$

$$\sum_1^j j^6 = \frac{j(j+1)(2j+1)}{42}[3j^4+6j^3-3j+1]$$

We are then faced with the solution of finite difference equations of the type

$$u_{x+2} - u_x = \alpha + \beta x + \gamma x^2 + \delta x^3 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (5)$$

which give us at once by finite integration the initial and final rotational functions.

Thus

$$u_{x+2} - u_x = [(1 + \Delta)^2 - 1]\, u_x = [\Delta^2 + 2\Delta]\, u_x.$$

To obtain u_x we have to operate on the right hand side of equation (5) with

$$\frac{1}{\Delta^2 + 2\Delta} = \frac{1}{2\Delta}(1 + \tfrac{1}{2}\Delta)^{-1} = \tfrac{1}{2}\left\{\frac{1}{\Delta} - \tfrac{1}{2} + \frac{\Delta}{4} - \frac{\Delta^2}{8} + \frac{\Delta^3}{16} \ldots\right\}^*.$$

Expressed as a series of factorials the integrand is

$$\alpha + (\alpha + \beta + \gamma + \delta)\, x^{(1)} + (\gamma + 3\delta)\, x^{(2)} + \delta x^{(3)},$$

so that finally we have after operating

$$u_x = \tfrac{1}{8}\delta x^{(4)} + (\tfrac{1}{6}\gamma + \tfrac{1}{4}\delta)\, x^{(3)} + (\tfrac{1}{4}\beta - \tfrac{1}{8}\delta)\, x^{(2)} + (\tfrac{1}{2}\alpha - \tfrac{1}{4}\beta + \tfrac{1}{8}\delta)\, x^{(1)} + (-\tfrac{1}{4}\alpha + \tfrac{1}{8}\beta - \tfrac{1}{16}\delta)$$
$$= \tfrac{1}{8}\delta x^4 + (\tfrac{1}{6}\gamma - \tfrac{1}{2}\delta)\, x^3 + (\tfrac{1}{4}\beta - \tfrac{1}{2}\gamma + \tfrac{1}{2}\delta)\, x^2 + (\tfrac{1}{2}\alpha - \tfrac{1}{2}\beta + \tfrac{1}{3}\gamma)\, x - \tfrac{1}{4}\alpha + \tfrac{1}{8}\beta - \tfrac{1}{16}\delta. \quad (6)$$

To this should be added the complementary function, which in this case is given by $(E^2 - 1)\, u_x = 0$—*i.e.*, $a\,(1)^x + b\,(-1)^x = C$, an absolute constant. The value of $F(n', j - \varepsilon)$ can therefore be at once written down, since the coefficients of equation (6) can be found from α, β, γ, δ of equation (3). The same process applies to $f(n'', j - \varepsilon)$.

The theory of band spectra developed by KRATZER (10) and others indicates that

$$\left.\begin{aligned} F(j - \varepsilon) &= A'(j - \varepsilon)^2 + B'(j - \varepsilon)^4 \\ f(j - \varepsilon) &= A''(j - \varepsilon)^2 + B''(j - \varepsilon)^4 \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (7)$$

where $A = \dfrac{h}{8\pi^2 I' c}$, etc., and $B = -\dfrac{4A^3}{\omega_n{}^2}$ where ω_n = "frequency" of nuclear vibrations when the molecule has n vibrational quanta (B, A and ω are all in wave-number units). Comparing coefficients of equations (6) and (7), we can determine the values of A, B and ε, and thus secure fundamental information about the emitting molecule.

Thus

$$B = \tfrac{1}{8}\delta \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (8)$$

$$-4\varepsilon B = \tfrac{1}{6}\gamma - \tfrac{1}{2}\delta \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (9)$$

$$A + 6\varepsilon^2 B = \tfrac{1}{4}\beta - \tfrac{1}{2}\gamma + \tfrac{1}{2}\delta \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (10)$$

$$-2\varepsilon\,(A + 2\varepsilon^2 B) = \tfrac{1}{2}\alpha - \tfrac{1}{2}\beta + \tfrac{1}{3}\gamma. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (11)$$

* I am indebted to Prof. W. B. MORTON for pointing out this convenient method to me.

In practice equations (9), (10) and (11) were used for the determination of A, B and ε. The value of B from equation (8) was not usually in agreement, and is probably less reliable, since the term is very small and more likely to be vitiated by errors arising from the neglect of $C(j - \varepsilon)^6 \ldots$, etc., in equation (7).

V. *The* λ 5165 *Band.*

The data associated with this band are recorded in Table I. In this case the prolonged development of the fine structure under arc conditions is very suitable for measurement and analysis, as it is but little confused by subsequent heads of the group. The band is typical in its structure of all the bands of the system, and it will therefore be considered in detail. More particularly it is of interest as being the radiation from the molecule in its vibrationless state.

Upon examining the list of wave numbers of, for example, the first members of the "Head" Triplets it will be observed that their first differences appear to go in pairs of approximately equal value, and the second differences as a consequence oscillate from a small value, say 0 or 0·1 up to 0·4 or 0·5 This feature becomes more pronounced as we recede from the head, and it is very evident if we examine the mean of the second and third members (the mean being taken since these components merge at a comparatively small distance outwards). The same characteristic is found in the "Tail" Triplets. The phenomenon is illustrated by the example given in Table VII, which is selected from a list of second members of the Tail system.

TABLE VII.

19463·38			511·06		(0·58)
	7·41			8·93	
470·79		(0·11)	519·99		(—0·04)
	7·52			8·89	
478·31		(0·42)	528·88		(0·53)
	7·94			9·42	
486·25		(0·06)	538·30		(—0·07)
	8·00			9·35	
494·25		(0·46)	547·65		
	8·46				
502·71		(—0·09)			
	8·35				

Two courses are now open to us :—

(1) We may either interpret this as some unusual staggering or displacement of alternate lines, in which case the whole "Tail" system would constitute an R branch, and the "Head" system the P branch of the band ; or

(2) We may break up the members into two series, which are naturally interpreted as P and R series. In the latter case the "Tail" and "Head" systems are complete partial bands each consisting of a P and R branch. Partial bands of this kind, which are closely related together, are familiar in the Helium band spectrum.

The latter alternative was at first adopted, and a considerable amount of analysis made on this basis. Subsequently it was abandoned, and the first alternative is regarded as the correct one. Before going into the details of this it has been thought well to give the substance of the results found by exploring the second hypothesis. For this purpose the old terms "Head" and "Tail" system are used for convenience. A characteristic difference between the Head and Tail systems is the headless character of the latter. Though an unusual feature, this would not be impossible of explanation with the zero line close to the head, and a somewhat gradual rise of intensity outwards. It is, however, only one of several anomalies associated with the spectrum. It was at first hoped that one system might be interpreted as two Q branches (a normal and a displaced one) associated with the other system, but this is clearly seen to be impossible, as the extrapolation to the head of the one is nowhere near the zero line of the other. The chief advantage of exploring the second alternative lies, however, in the natural explanation it affords of the staggering of alternate members. An examination of the "Head" system on this basis at once led to difficulties. A careful search through the head failed to reveal any gap or well defined intensity distribution such as usually points to the position of the null line. There is a somewhat questionable minimum of intensity at the 5161·7 triplet (see Table I, $\nu = 19368 \cdot 1$), and if we are prepared to make the doubtful assumption that under some circumstances the zero-line may not be actually absent, but only weak, we may derive plausible molecular constants by taking the above as zero-line. If this is the zero-line, then by application of the combination principles of equation (2) it should be possible to locate the zero-lines of the heads λ 5635 and λ 4737, since these have, respectively, the same initial and the same final states as λ 5165. If we choose the triplet at $\nu = \left.\begin{matrix} 17750 \cdot 53 \\ 17751 \cdot 24 \end{matrix}\right\}$ in the λ 5635 band, this gives tolerably good agreement of $R(j+1) - P(j)$ for small values of j. There is no line in the 4737 band which is a satisfactory choice: the triplet at $\left.\begin{matrix} 21117 \cdot 80 \\ 21118 \cdot 11 \end{matrix}\right\}$ is the nearest approach. In any case, there is no evidence of any intensity distribution about these lines for either the 5635 or 4737 bands. Further, no other line in the 5165 band may be chosen as zero line which will give any better agreement when the combination principle is applied to this and the other bands. All the evidence, therefore, points to the abandonment of these suggestions. Before doing this, however, a number of extensive calculations were made on the data of the 5165 "head" system, after the plan suggested in Section IV. Owing to the rapid approach of the second and third components of the triplets, the mean of these was used. Least squares' values of the constants α, β, γ and δ were found for the first and the second and third members for both the initial and final states. The final results were :—

Initial State—

First Members .. $F(m) = 2 \cdot 69636 \, (j - 0 \cdot 49157)^2 - 0 \cdot 003035 \, (j - 0 \cdot 49157)^4$

Second and Third Members $F(m) = 2 \cdot 68351 \, (j - 0 \cdot 48742)^2 - 0 \cdot 003688 \, (j - 0 \cdot 48742)^4$

Final State—

First Members .. $f(m) = 2 \cdot 22671\,(j - 0 \cdot 49517)^2 - 0 \cdot 003119\,(j - 0 \cdot 49517)^4$

Second and Third Members $f(m) = 2 \cdot 21730\,(j - 0 \cdot 49935)^2 - 0 \cdot 003105\,(j - 0 \cdot 49935)^4$.

From these we should have for the initial and final values of the moment of inertia (by equation 7) $10 \cdot 266 \times 10^{-40}$ and $10 \cdot 316 \times 10^{-40}$ initially, and $12 \cdot 432 \times 10^{-40}$ and $12 \cdot 485 \times 10^{-40}$ finally. The internuclear distance (d) may be calculated from these, since for a diatomic molecule consisting of two nuclei, masses m_1 and m_2, at a distance "d" apart:

$$I = \frac{m_1 m_2}{m_1 + m_2} \cdot d^2.$$

The above data give 0·978 and 0·981 Å.U. initially, and 1·077 and 1·079 Å.U. finally, if we assume that the molecule consists of two nuclei, each of mass 13 times that of the H atom. This would be an approximation to an HC–CH molecule, but discussion of this is reserved for a later section. The above values of "d" are possible, but somewhat lower than might be expected from such a molecule. The moments of inertia were derived by a graphical method (see Section VI) for the "head" system in the case of six bands, and for the "tail" system in the case of twelve bands; but no useful purpose would be served by presenting the now discarded data. Under the same general hypothesis of two partial bands—viz., the "Head" and "Tail" systems—a further possibility was explored, and it is perhaps worth mentioning. Examination of the "Head" system of the 5165 band showed that one triplet at about λ 5127 ($\nu = 19197$) was absent. Plate 4 No. 4 shows this position marked as P (49). There was no triplet absent in the other branch of the system, so that its interpretation as due to a perturbation seemed impossible. Assuming this to be the null line of the band, an assignment of quantum numbers and a detailed analysis was then made. As before, least squares' solutions of α, β, γ and δ were obtained, and the rotational terms were found to be :—

Initial—

First Members .. $F(m) = 8 \cdot 52557\,(j - 0 \cdot 50036)^2 - 0 \cdot 003633\,(j - 0 \cdot 50036)^4$

Second and Third Members $F(m) = 8 \cdot 52517\,(j - 0 \cdot 49014)^2 - 0 \cdot 001159\,(j - 0 \cdot 49014)^4$

Final—

First Members .. $f(m) = 7 \cdot 98405\,(j - 0 \cdot 48437)^2 - 0 \cdot 006017\,(j - 0 \cdot 48437)^4$

Second and Third Members $j(m) = 8 \cdot 03329\,(j - 0 \cdot 49217)^2 - 0 \cdot 002883\,(j - 0 \cdot 49217)^4$

In the final rotational terms the constant 8·033 is probably more reliable than 7·984, since the $R(j) - P(j+1)$ data of the latter included a number of doubtful figures.

For the initial moment of inertia we have $h/8\pi^2 I'c = 8 \cdot 52537$, or $I' = 3 \cdot 2470 \times 10^{-40}$. Assuming a CH molecule, this gives $d = 1 \cdot 460 \times 10^{-8}$ cm., whereas assuming a C_2H_2

molecule (say two nuclei of mass 13), $d = 0{\cdot}55 \times 10^{-8}$ cm. The former value of d is quite reasonable for such a molecule, the latter is impossible. Assuming a CH molecule, the final moment of inertia is $I'' = 3{\cdot}4459 \times 10^{-40}$, giving $d = 1{\cdot}504 \times 10^{-8}$ cm. There is thus an increase of some 6 per cent. in I during the electron transition. The closeness of ε to $\frac{1}{2}$ in all four equations is very notable. While the values of A are probably reliable, the coefficient B (of the fourth-power term) is subject to a considerable percentage error owing to its inherent smallness. Hence, upon forming

$$R(j) - [F(j+1) - f(j)] \quad \text{and} \quad P(j) - [F(j) - f(j+1)],$$

which should be constant—there is found a considerable falling off for increasing values of j. The theoretical values of B (see equation 7), viz., 0·00079176 (initial) and 0·00078366 (final) were tested, and also the effect of adopting $\varepsilon = \frac{1}{2}$ exactly, but no satisfactory fit was found in any case.

The assumption of partial bands is therefore finally abandoned, and the so-called "Tail" system is to be regarded as the positive branch and the "Head" system as the negative branch of a normally developed band. The staggering of the alternate members of the branches will be discussed later (*vide* Section VII). We now have an intensity distribution of the normal type, which serves as a guide to the location of the null line. We also have an exact criterion, since in the R branch there is a missing triplet at λ 5049 ($\nu = 19800$), and this may be naturally connected with that which was missing in the P branch at λ 5127. These two triplets will therefore have a common rotational state, which for some reason is rendered unstable. It may be either an initial or final state which they have in common, though the initial state (being the excited state) would *a priori* seem more probable. By extrapolation of the P branch round the head and towards the zero line (in which region its members are not measurable), it was found that there were 95 members between these two gaps. These correspond to j-transitions of $49 \rightarrow 48$ and $49 \rightarrow 50$, and indicate a disturbance of the initial state 49. The complete assignment is given in Table I. By application of the combination principle the assignment of j-values was then made to the 5635 and 4737 heads, and afterwards to most of the other principal heads. Some ten heads have been completely classified in this way, and one partially so. The full detail is found in Tables I, II, III and IV. Owing to the crowding of lines near the head, and the additional complications of the triplet structure, it was impossible to obtain reliable measurements of the P branch below about P(18). In the formation of the combination differences of equation (2) the accurate measurements of R(2) to R(18) are therefore unfortunately not utilised.

In bands in which the branches fade out at about $j = 30$, this involves neglecting some of the most accurate data. It would not at first sight appear to be a serious feature in the λ 5165 band, and accordingly a least squares' treatment of the data of Table VIII was made. This gave, however, very improbable values for A and ε, and it was therefore abandoned in favour of a graphical method. It is perhaps not surprising that an extrapolation from $j = 18$ to 0—which is really what is asked from the formula—should prove

TABLE VIII.

	Initial State R (j + 1) — P (j).		Final State R (j) — P (j + 1).	
j.	1st Members.	2nd and 3rd Members.	1st Members.	2nd and 3rd Members.
18			113·05	113·52
19	128·58	128·92	119·46	119·93
20	135·43	135·81	126·07	126·40
21	142·48	142·78	132·40	132·77
22	149·29	149·56	138·95	139·26
23	156·33	156·54	145·51	145·58
24	163·32	163·36	151·77	152·05
25	170·10	170·33	158·08	158·40
26	176·89	177·18	164·63	164·84
27	183·90	184·06	170·97	171·25
28	190·65	190·84	177·44	177·63
29	197·73	197·78	183·74	183·95
30	204·41	204·57	190·29	190·39
31	211·25	211·49	196·51	196·65
32	218·10	218·19	202·83	203·09
33	224·98	225·12	209·23	209·34
34	231·71	231·83	215·60	215·75
35	238·60	238·72	221·82	221·99
36	245·12	245·37	228·27	228·36
37	252·15	252·23	234·37	234·59
38	258·83	258·92	240·82	240·94
39	265·64	265·74	247·02	247·14
40	272·26	272·32	253·36	253·45
41	279·10	279·21	259·53	259·60
42	285·71	285·78	265·83	265·98
43	292·49	292·58	272·00	272·08
44	299·05	299·12	278·28	278·35
45	305·82	305·87	284·38	284·45
46	312·40	312·43	290·66	290·74
47		—	296·76	296·81
48		325·69		—
49		—		309·11
50		338·87		315·32
51		345·63		321·33
52		352·04		327·59
53		358·70		333·49
54		365·10		339·68
55		371·73		345·63
56		378·09		351·78
57		384·72		357·69
58		391·03		363·82
59		397·65		369·66
60		403·87		375·80
61		410·47		381·65
62		416·68		387·72
63		—		392·51
64		—		399·41
65		—		405·80

unreliable. In any case it seems likely that the total quantum number j involves a finite σ [$m = \{\sqrt{j^2 - \sigma^2} - \varepsilon\}$ the "Kramers-Pauli" (11) Term]. In this case equation (7) is replaced by

$$F(m) = \varepsilon\sigma^2 (A + 2\varepsilon^2 B) 1/j + [A(\varepsilon^2 - \sigma^2) + B\varepsilon^2 (\varepsilon^2 - 6\sigma^2)] - 2\varepsilon [A + (2\varepsilon^2 - 3\sigma^2) B] j + [A + 2B(3\varepsilon^2 - \sigma^2)] j^2 - 4B\varepsilon j^3 + Bj^4 \quad . \quad . \quad . \quad (12)$$

It is perhaps noteworthy that in connection with the second positive band spectrum of Nitrogen, with which a comparison will be made later, BIRGE (12) writes: "In the graphs (*i.e.*, the $\Delta F : m$ curves) for the two outer components of the triplets in the Nitrogen second group bands, this curvature (*i.e.*, corresponding to a finite σ and ε) is found in both the initial and final conditions."

If this is so in the case of the Swan bands, then the j^{-1} term of equation (12), which is negligible for large values of j, would become important near the origin.

The second order plates used for our measurements are excellent so far as they go, but it is clear that third or fourth order photographs on a 21-foot (or larger) grating are very desirable in order to secure accurate measurements of P (1) to P (18).

VI. *Graphical Determination of Moment of Inertia.*

It is perhaps well to be explicit about the detail of the graphical method of finding moments of inertia, in view of the slightly different general transition and notation used throughout the work. The method is due to BIRGE, and is described and applied by CURTIS (13) in his analysis of the Helium bands.

The general transitions adopted for the two branches have been:

(R) branch. $j + 1 \rightarrow j$ where $j = 1, 2, 3$, etc. \
(P) branch. $j \rightarrow j + 1$ where $j = 1, 2, 3$, etc. } j is the total quantum number.

The formulæ for typical lines R(j) and P(j) in the positive and negative branches are therefore

$$\left.\begin{aligned} R(j) &= \nu_0 + \frac{h}{8\pi^2 I'} (j - \varepsilon + 1)^2 - \frac{h}{8\pi^2 I''} (j - \varepsilon)^2 \\ P(j) &= \nu_0 + \frac{h}{8\pi^2 I'} (j - \varepsilon)^2 - \frac{h}{8\pi^2 I''} (j - \varepsilon + 1)^2 \end{aligned}\right\} \quad . \quad . \quad . \quad (13)$$

if for purposes of graphical construction we neglect the change in ε and the fourth power term during the electronic transition. These become—using one accent and two accents, respectively, for the initial and final states (see equation 7):—

$$\left.\begin{aligned} R(j) &= \nu_0 + A' - 2A'\varepsilon + C\varepsilon^2 + 2j(A' - C\varepsilon) + Cj^2 \\ P(j) &= \nu_0 - A'' + 2A''\varepsilon + C\varepsilon^2 - 2j(A'' + C\varepsilon) + Cj^2 \end{aligned}\right\} \quad . \quad . \quad . \quad (14)$$

where $A' = h/8\pi^2 I'$ (Initial), and $A'' = h/8\pi^2 I''$ (Final), and $C = A' - A''$. If $\varepsilon = \frac{1}{2}$, these simplify to :—

$$\left.\begin{aligned} R(j) &= (\nu_0 + C/4) + j(A' + A'') + Cj^2 \\ P(j) &= (\nu_0 + C/4) - j(A' + A'') + Cj^2 \end{aligned}\right\} \quad (15)$$

In the latter case we have the equations for the first differences :—

$$\left.\begin{aligned} R(j) - R(j-1) &= (A' + A'') + C(2j-1) \\ P(j-1) - P(j) &= (A' + A'') - C(2j-1) \end{aligned}\right\} \quad (16)$$

At $j = 1$ these give, respectively, $2A'$ and $2A''$. By plotting the data of equation (16) we may therefore determine A' and A'' graphically. From the graphical standpoint it is, however, an advantage to have the two branches collinear, and the two branches of equation (16) become so if we plot $R(j) - R(j-1)$ at $(j - \frac{1}{2})$ and $P(j-1) - P(j)$ at $(j - \frac{1}{2})$. The values of $2A'$ and $2A''$ are then read off at $j = \frac{1}{2}$ in the two branches.

If, however, $\varepsilon \neq \frac{1}{2}$, then the difference equations are, from (14),

$$\left.\begin{aligned} R(j) - R(j-1) &= 2(A' - C\varepsilon) + C(2j-1) \\ P(j-1) - P(j) &= 2(A'' + C\varepsilon) - C(2j-1) \end{aligned}\right\} \quad (17)$$

We see that at the values $j = (\frac{1}{2} + \varepsilon)$ these reduce to $2A'$ and $2A''$. Equations (17) are not, however, collinear. They become so if we write $j' + \varepsilon$ for j, so that we must plot the quantity $R(j) - R(j-1)$ at $(j - \varepsilon)$, etc., and the values [$2A'$ and $2A''$] are then found as before at $j = \frac{1}{2}$ on each side of the origin.

The above graphical method has been used on a large scale for all the bands analysed, and determines the moment of inertia within a probable error of $\frac{1}{2}$ per cent. At the same time, the value of C can be found very accurately from the graph, since $\Delta^2 R(j) = \Delta^2 P(j) = 2C$ is the gradient of the straight lines obtained. In practice the graph of the first differences against j (as in equation 17) is extremely useful in determining the numbering of the lines in the first instance. For, assigning any arbitrary numbering consistent with the perturbations $R(x)$, $P(x+1)$, and plotting the difference equations of (17) we have merely to displace the two branches symmetrically from the origin so as to be collinear in order to obtain the true value of x.

In theory it should, of course, be possible to determine the important constants A' and A'', B' and B'' by an analysis of one branch only, viz., the well developed R branch in this case. Assuming $\varepsilon = \frac{1}{2}$, then any line $R(j)$ would be given by

$$R(j) = \nu_0 + \frac{C}{4} + \frac{D}{16} + [(A' + A'') + \tfrac{3}{4}(B' + B'')]j + [C + 3/2D]j^2 + 2(B' + B'')j^3 + Dj^4,$$

where

$$D = B' - B''. \quad (18)$$

Neglecting B' and B'' this reduces to equation (15). An attempt was made to apply this to the well developed R branch of the λ 5165 head, but it was found that the "staggering" effect vitiated the results.

The graphically determined data—viz., the values of 2A′, 2A″ and C—are given in Table IX, and these have been used to derive Table X, which gives values of I′, I″, and d', d'', the corresponding values of the internuclear distance. The latter have been

TABLE IX.—Values of $\begin{bmatrix} 2A' & 2A'' \\ & C \end{bmatrix}$ (graphically).

n' \ n''	0.	1.	2.	3.	4.	5.
0	3·41 3·18 0·1151	3·41 3·145 0·132*	3·41 3·12 0·147			
1	3·37 3·18 0·0985	3·36 3·14 0·1125	3·37 3·12 0·128*	3·37 3·09 0·144		
2			3·34 3·125 0·107	3·355 3·11 0·123		
3					3·34 3·11 0·116	3·37 3·10 0·133

Note.—The middle components of the triplets were used in deriving the above data. An * indicates that the mean of the 2nd and 3rd components was employed.

TABLE X.—Values of I′ and I″, also of d' and d''.

n' \ n''	0.	1.	2.	3.	4.	5.
0	16·236 17·410 1·230 1·274	16·236 17·604 1·230 1·281	16·236 17·745 1·230 1·287			
1	16·428 17·410 1·238 1·274	16·477 17·632 1·240 1·283	16·428 17·745 1·238 1·287	16·428 17·918 1·238 1·292		
2			16·576 17·716 1·243 1·286	16·502 17·801 1·241 1·288		
3					16·576 17·801 1·243 1·288	16·428 17·860 1·238 1·290

Note.—The units in which I is given are 10^{-40} grm.-cm.; d the inter-nuclear distance is in Ångström Units.

deduced on the hypothesis of an HC–CH molecule, and are quite close to the similar values for molecules such as N_2, CO, etc. A specific comparison of the details will be made later. It may perhaps be mentioned here that the assumption of a C_2 molecule—*i.e.*, of two nuclei of mass 12—would give values of d about 0·05 Å.U. larger, but this is still of the right order of size. A distinction between these alternatives on the basis of a structure analysis alone is therefore impossible. Against a C_2 origin there is, however, considerable experimental evidence (see Section XIII), and there are also theoretical considerations which make it highly improbable. Briefly, these are that a C_2 molecule would be of the inert gas type, and in accordance with our knowledge of these molecules it would not be expected to radiate. For instance, BN, which C_2 would resemble closely, is known to have no band spectra at all. (See MULLIKEN's paper (4)). Fig. 1 illustrates

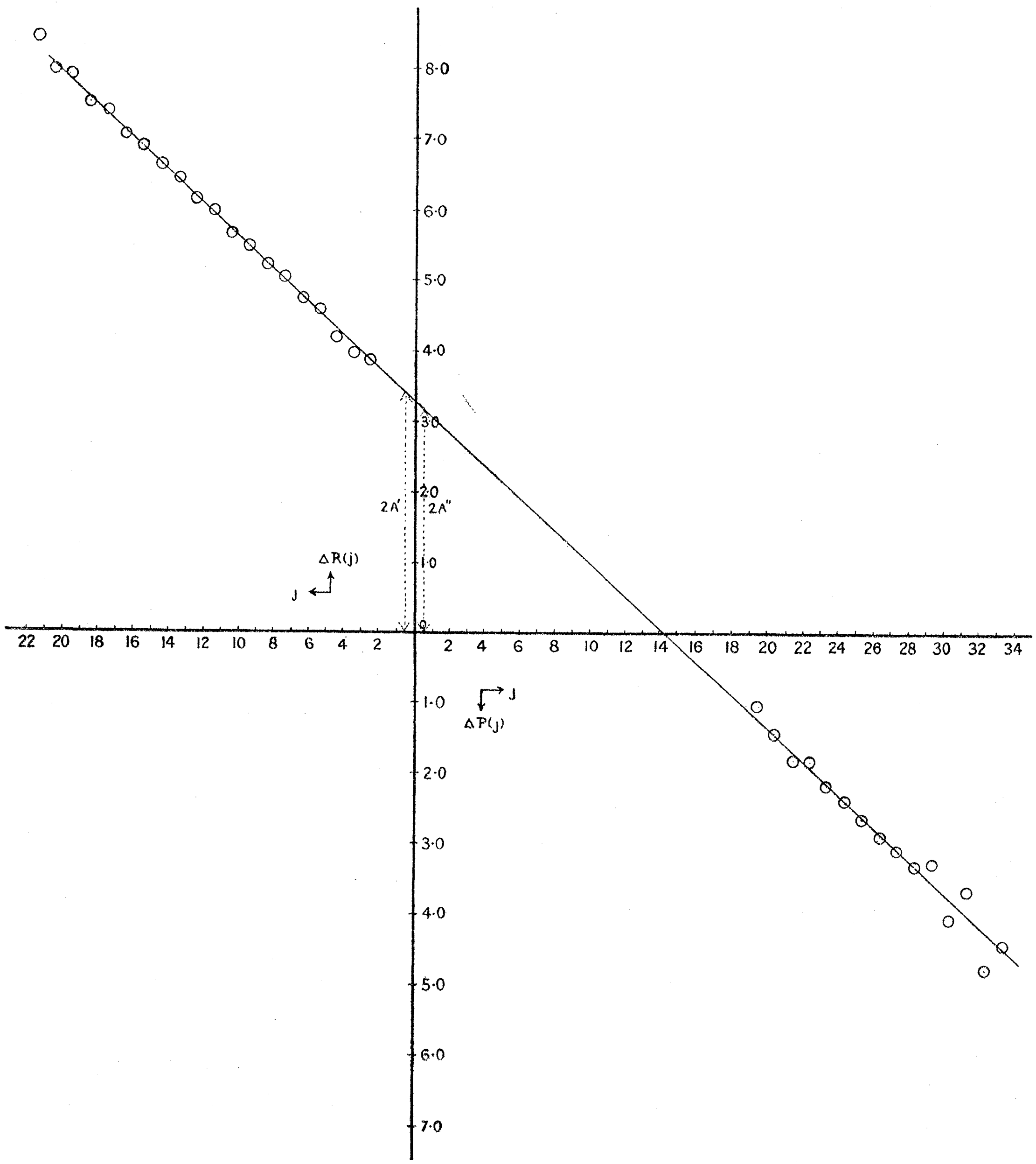

FIG. 1.

the graphical method in its application to the λ 5165 head. It also shows clearly the staggering effect: it will be noted that successive points are on opposite sides of the line.

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VII. *Observations on other Bands.*

Table XI illustrates the application of the combination principle to several of these bands. The heads 5165, 5635, 6191 all arise from the molecule in the same initial state $n' = 0$, while λλ 5165 and 4737 arise from the same final state $n'' = 0$. The agreement is quite good on the whole, and would probably be better still if the P branch was adequately resolved so that second members only could be used. In Table XI the

Table XI.

j.	Initial State $\overline{R(j+1)-P(j)}$.			Final State $\overline{R(j)-P(j+1)}$.	
	5165	5635	6191	5165	4737
17		115·08	115·00		
18		122·12	121·85	113·52	
19	128·92	129·06	128·91	119·93	
20	135·81	135·78	135·76	126·40	126·42
21	142·78	142·82	142·76	132·77	132·78
22	149·56	149·51	149·59	139·26	139·35
23	156·54	156·68	156·57	145·58	145·62
24	163·36	163·51	163·54	152·05	152·17
25	170·33	170·34		158·40	158·43
26	177·18	177·15		164·84	164·92
27	184·06			171·25	171·23
28	190·84			177·63	177·76
29	197·78			183·95	184·07
30	204·57			190·39	190·29

figures apply to means of the second and third members. The agreement in the case of first members was examined, but it is not so good, owing probably to the law of widening of the triplet structure being different for the various bands.

The 4737 band exhibits some features of interest. The triplet structure of the P branch is in this case unusually clear and well-defined. The triplet separation, however, shows an unusual feature as we proceed outwards from the head: it grows gradually less, until at P (30) it has vanished. Beyond this point it resumes a measurable value, and afterwards again decreases normally. The great intensity of the single line P (30) strongly suggests a definite merging of all three components at this point. In the arc photograph there is, however, a faint line in about the correct position for the first component: this may possibly be genuine, or it may have an extraneous origin.

Another anomalous feature is revealed by a study of the wave-numbers (mean of the second and third components) of the P branch. Some of these are recorded with their first differences in Table XII. It will be noted that a definite but only slight staggering (and that of practically constant amount) takes place up to P (32). After this point

TABLE XII.

ν.	Δν.	Δ²ν.	ν.	Δν.	Δ²ν.
21106·80			21136·37		—1·12
	0·98			2·96	
107·78		+0·24	139·33		+1·42
	1·22			4·38	
109·00		+0·23	143·71		—0·82
	1·45			3·56	
110·45		+0·13	147·27		+1·32
	1·58			4·88	
112·03		+0·27	152·15		—1·07
	1·85			3·81	
113·88		+0·13	155·96		+1·31
	1·98			5·12	
115·86		+0·27	161·08		—0·82
	2·25			4·30	
118·11		+0·13	165·38		+1·41
	2·38			5·71	
120·49		+0·34	171·09		—0·96
	2·72			4·75	
123·21		+0·09	175·84		+1·15
	2·81			5·90	
126·02		—1·18	181·74		—0·86
	1·63			5·04	
127·65		+3·01	186·78		+1·37
	4·64			6·41	
132·29		—0·56	193·19		—0·96
	4·08			5·45	
			198·64		

P (33) is violently perturbed—viz., by 1·45 units—and the subsequent staggering becomes very pronounced, the second differences oscillating between positive and negative values. A closer examination shows that the staggering occurs in the alternate members—viz., P (35), P (37), etc.—since P (32), P (34), P (36), etc., are in about the expected positions. The perturbation of position is accompanied by one of intensity. It will be noticed that the intensity of P(33) is abnormally low. Fig. 2 shows clearly the nature of the

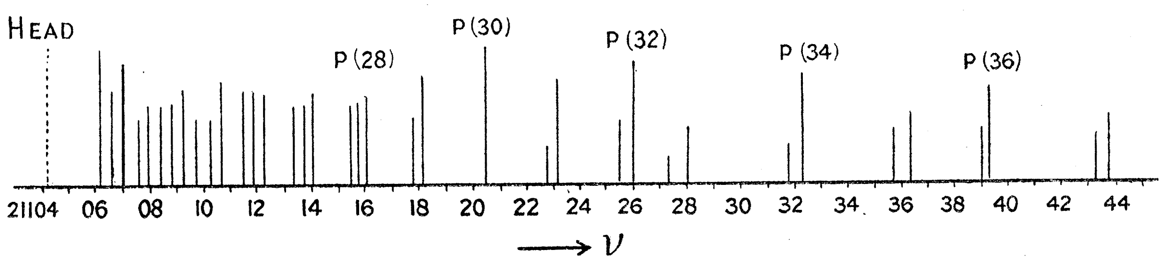

FIG. 2.

perturbation and the staggering effect. The heights of the lines are drawn proportional to the estimated intensities. Presumably R(32) shows a similar perturbation, but this is not determinable from the data of the R branch, which fades out about this point. The cause of the staggering effect is quite obscure. It is suggested, however, that it may be related to the peculiar "staggering" of intensities which characterises a number of band spectra arising from symmetrical molecules—*e.g.*, He_2, N_2, N_2^+, etc. In connection with the latter phenomenon, DIEKE (14) has suggested the division of the bands into two series, which would necessarily involve reducing the moment of inertia of the molecule. BIRGE (15) has, however, urged weighty objections against this view. A recent suggestion of SLATER (16) is interesting in this connection. We have already considered DIEKE's alternative in relation to the Swan bands, but decided to abandon it. While the origin of both these phenomena is still very uncertain, it may well be that they are different manifestations of the same cause, more especially as we believe the emitter of the Swan bands to be a highly symmetrical one.

In the 4715 head (and the succeeding heads) the triplets of the R branch are not at all obvious, and this, together with the smaller dispersion of the grating in this position, and the overlapping structure of the fourth head, has made it very difficult to analyse. The assignment made of some 18 members of the R branch is therefore only tentative, and cannot be checked by the combination principle, since the P branch is a confused tangle of lines. There are some irregularities in the assignment made, but as given it accounts for most of the strong lines. Measurements made on good plates of still higher dispersion are desirable, and, in addition, further and more extensive measurements of the (3, 3), (3, 4) and (3, 5) bands (which have the same initial state) would be of value.

An Alternative Explanation of the Band Structure.—Before leaving the fine structure analysis of the bands, a further possibility may be worth mentioning. Adopting the general grouping of the lines already considered, we could avoid the phenomenon of staggering by considering the whole as made up of two systems superposed, and having very nearly, but not quite, the same origin (ν_0). Alternate members in the two branches would then belong to the same P or R branch. If these were regarded as a whole quantum and a half quantum system superposed (as shown in fig. 3), arising, of course, from the

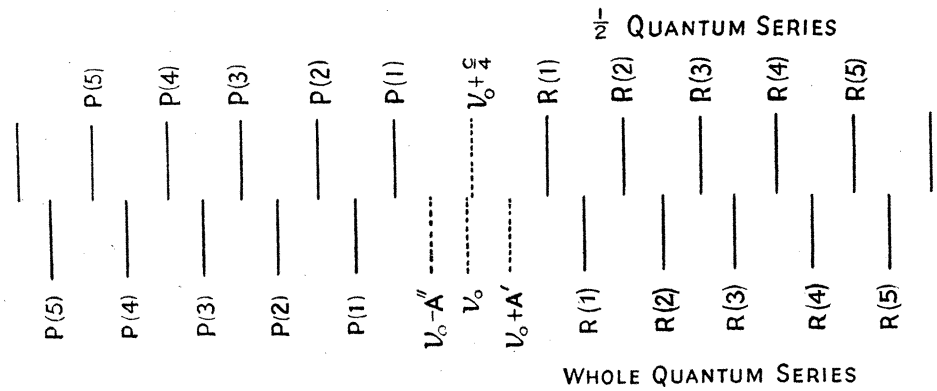

FIG. 3.

one molecule, it would account qualitatively for all the facts. Such systems, it is well known, extrapolate for $j = 0$ to ν_0 and $\nu_0 + C/4$, respectively. This would correspond to a displacement of about 0·03 frequency units at the origin. If C $[= h/8\pi^2 (1/\mathrm{I}' - 1/\mathrm{I}'')]$ is a function of m, as is to be expected, owing to the distension of the molecule by centrifugal force, then we may expect an increasing stagger or displacement of the two systems for large values of m. This is, in fact, the case, the staggering becoming as large as 0·6 units at $j = 70$ (it would be at $j = 35$ on this hypothesis).

If this view is correct, it should be possible to relate mathematically the triplet separation as a function of m, and the "staggering" as a function of m, for in Section IX we have also considered the former as originating in centrifugal deformation of the molecule.

A serious objection to breaking up the band structure into two bands governed by whole and half-quantum transitions is that the moments of inertia of the molecule will then have only half the values of Table X. In the case of the 5165 band, for example, we should then have for the internuclear distances $0 \cdot 87 \times 10^{-8}$ cm. initially, and $0 \cdot 90 \times 10^{-8}$ cm. finally, which are too small, as seen by comparison with the data of other similar molecules, for which d is about $1 \cdot 2 \times 10^{-8}$ cm.

VIII. *An Anomalous Feature of Arc Development.*

The development of the P branches of the different bands examined shows a notable difference, according as it is produced in the arc or in the tube. While the tube photographs show a normal development of triplets, the arc photographs show doublets only. This peculiarity of the arc photographs has also been observed by Shea,* who regards the third component as missing. The phenomenon appears to be quite genuine, and not merely a question of inadequate resolving power. A close examination of the 4737 band, which shows an unusually good development of the P branch triplets on the tube plates, leads me to think that it is not merely an elimination of the third component which takes place in the arc, but rather an anomalous displacement of the central and third components together so that they are not resolved. Both the intensity and the position of the "doublet" appear to me to favour this. The matter would, however, be worth a further investigation with still higher dispersion and resolving power.

Anomalies of this kind are not unknown in band spectra, and they present a problem of considerable interest. For example, in the case of the Comet Tail bands due to CO^+, the development by electron impact in low-pressure CO gas produces a P, Q and R branch together with a strong additional Q branch. This latter does not appear at all in the structure development when a trace of CO is contained in high pressure Helium (17). There is again a curious difference between the high temperature conditions of the arc and the low temperature conditions of active Nitrogen on the fine structure development of the β bands of BO (18). [In active Nitrogen they are singlet bands, while in the arc they are doublets of increasing separation outwards. The amount of separation appears to depend to a considerable extent upon the value of n''.] These bands are apparently anomalous in any case, and, according to Mulliken, consist of single positive branches.

* Private communication.

It might be, however, that the " heads " are exactly coincident with a structure line in which case the P and R branches would superpose. If so, a high dispersion photograph should probably show the breaking up of the additional component into two members for large values of m, unless the zero line were extremely close to the head. It would be very interesting to examine the development of the violet CN bands in excess of Argon or in active Nitrogen.

A further interesting case is recorded by STEUBING and TOUSSAINT (19), who give some good micro-photometric curves showing the fine structure of the second positive Nitrogen bands. These are of particular interest in view of the probable similarity of the N_2 molecule in this state, and the HC–CH molecule when emitting Swan bands. The curves show the normal development of the triplet structure at low and high temperatures. The effect of temperature is simply to increase the value of $j_{max.}$— while not differentiating between the components of a triplet. When a trace of nitrogen is mixed with excess of Helium-Neon mixture, and a condensed discharge passed, the fine structure is similar to that from a trace of Nitrogen in excess of Argon, excited by an uncondensed discharge, and both are different from the normal production. From being of approximately equal intensity under normal conditions, the graphs indicate that the triplet components become quite unequal. This phenomenon is different to that of the P branches of the Swan bands. It should be said, however, that these observations of STEUBING and TOUSSAINT were obviously made on the R branches of the second positive Nitrogen bands: the P branches were not adequately resolved for observation. It may be that somewhat similar intensity changes in the R branches of the Swan bands would be revealed by a microphotometer.

It is impossible to submit any wholly satisfactory explanation of the differences between arc conditions and the conditions in high pressure Argon until we understand more of the nature and causes of fine structure multiplicity. Some speculations in this connection are presented in the next section. The measure of similarity between conditions of production in high pressure Argon and in active Nitrogen may, however, be noted. The writer has drawn attention to this on several occasions (20). Probably the close similarity is due chiefly to the excitation being by means of collisions of the second kind with excited Argon atoms and excited Nitrogen molecules, respectively.

IX. *The Fine Structure Multiplicity.*

Bands have been classified by HEURLINGER on the basis of their fine structure as singlet, doublet and triplet bands. The singlet bands may consist of either single lines or doublets of increasing separation outwards (*e.g.*, the BO bands in the arc, and the violet CN bands). Doublet and triplet bands have decreasing separation outwards, and, in addition, each component may show doublet separation of the first type. It is clear that the Swan bands are an example of the Heurlinger Triplet bands. KRATZER has explained the doublet bands by assuming that such molecules will have a resultant electronic momentum, and that the molecule may rotate so that its own angular momentum is either in the same or in the opposite direction to this. It would then follow that while under arc conditions both directions of rotation were possible for the BO molecule, in active Nitrogen only one direction was possible. [A *résumé* of these and other facts is given by Mulliken in the papers already cited (4, 18).] The physical mechanism of this is, however, difficult to picture. Birge (12) has indicated several directions in which Kratzer's theory disagrees with experimental data in the case of the CN doublets. The calculated doublet width and symmetry of the separation both conflict with the experimental data.*

Curves have been drawn which exhibit the triplet separation as a function of the rotational quantum number. Fig. 4 shows the triplet widths of the 5165 band. Those for the 5635 and 4737 bands have been constructed, but are not reproduced here, as they exhibit precisely similar characteristics to those of fig. 4. The rapid separation of the components near the origin is very remarkable. The two intervals $w_{1,2}$ and $w_{2,3}$ between the first and second and the second and third components have been plotted positively and negatively. Such a curve as fig. 4 provides the essential data for a rigorous quantitative test of any theory of fine structure multiplicity. As no immediate purpose would appear to be served, the equations to these curves have not been found. They appear to the eye to approximate to hyperbolæ. The curve is for the R branch only; there is not sufficient data to plot the P branch separations. These appear, however, to be somewhat smaller than the R branch separations of the corresponding triplets (*i.e.*, of those having the same quantum numbers). It will be seen from fig. 4 that the two outer components behave differently, and they will therefore require different functions to represent their separation from the central (normal) one. It is impossible, within the limits of error, to choose any line parallel to the major axis so as to reflect the one curve into the other. The interval $w_{1,2}$ appears to assume a constant value for large values of j, and the interval $w_{2,3}$ appears to vanish at about $j = 50$. In reality, however, it may be that both approach zero asymptotically, but at vastly different rates. A notable feature of the curves is that for the $w_{1,2}$ interval there is a staggering of the alternate members; for the $w_{2,3}$ there is none. This has been indicated by constructing two curves through the alternate points in the former case.

With regard to the origin of the triplet structure of this type, it would seem possible to generalise the principle of Kratzer's explanation of the doublet bands, if we suppose that a two-valence electron emitter (such as the HC–CH molecule) may have its two electrons traversing their orbits in the same sense in some of the molecules, and in the opposite sense in others. There seems to be no *a priori* reason against the assumption, for, like the isotopes of elements, there would be no chemical means, and probably few physical means, of differentiating between the one type of C_2H_2 molecule and the other. [I have

* *Note added later*: I understand that the above disagreement arose through an arithmetical error. Kratzer's theory therefore provides quite a satisfactory explanation of the doublets.

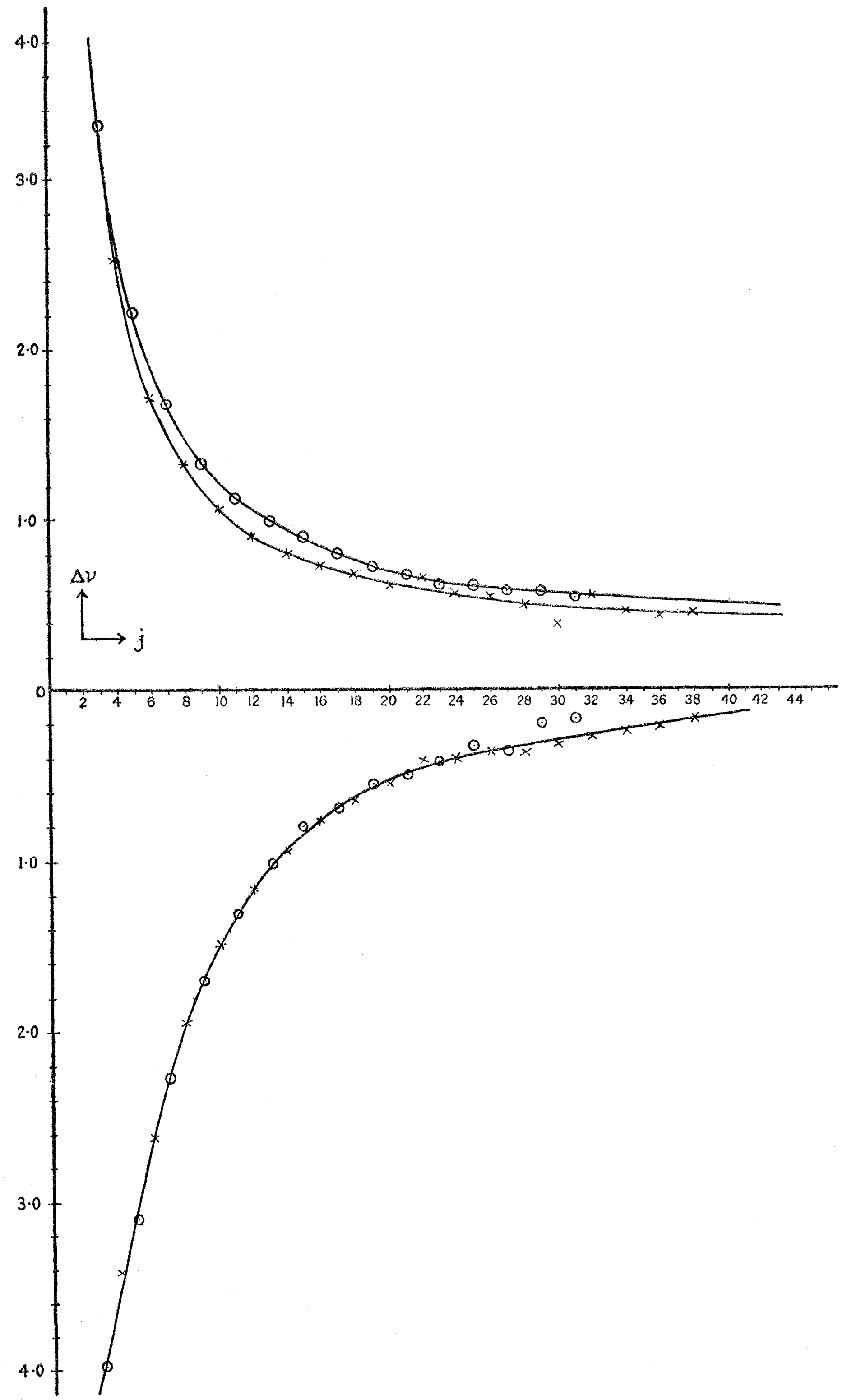
4·0
3·0
2·0
1·0
Δν
j
0
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44
1·0
2·0
3·0
4·0

FIG. 4.

not been able to find any data, but probably C_2H_2 is diamagnetic. Even if it is, I do not think that the above suggestion should give rise to any difficulty.] On the above hypothesis it would be possible to combine the resultant electronic momentum in the three cases of fig. 5 with the momentum of the rotating nuclei. Thus, if M represents

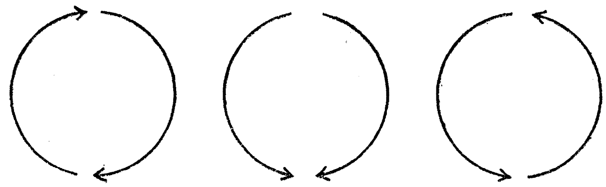

FIG. 5.

the angular momentum of the core, and A and B the momentum contributions of the two electron orbits, the possibilities are illustrated by :—

$$\left.\begin{array}{l} M + (A + B)_m \\ M - (A + B)_m \\ M + (A - B)_m \\ M - (A - B)_m \end{array}\right\}$$

which in general should yield a quartet. But if as here we may reasonably assume the two-valence electrons to move in *similar* orbits, we may put $A = B$, and we have the three cases—$M + 2A_m$, M, $M - 2A_m$—which correspond to the triplet formation. (These formulæ are descriptive only, not quantitative.) The diminution in triplet separation with increasing rotational quantum number, indicates that the vector component of electronic momentum about the axis of rotation gradually falls off as m increases. (The dependence on m is indicated by the subscript.) This being so, the evaluation of ε as a function of m should be intimately related to the triplet separation as a function of m. This does not *necessarily* involve a change in the *resultant* electronic momentum, for σ may merely gain at the expense of ε, through the orientation of the electronic orbits being altered. On the other hand, it seems possible that the resultant electronic momentum *is* changed, for probably a change of size as well as of orientation of the valence orbits will be a consequence of the inevitable attempt to counteract the distension of the molecule under centrifugal force. It may be noted that in order to counteract the centrifugal force both these changes would necessarily be in the direction which would diminish ε, viz., contraction as regards size and orientation of the orbital planes perpendicular to the line joining the nuclei. This factor therefore accounts for triplet separations decreasing as m increases. One significant feature which is difficult to explain even qualitatively is the asymmetry of the triplet separation, viz., that $w_{1,2} \rightarrow$ constant = approximately 0·4 frequency units for large values of j, while $w_{2,3} \rightarrow 0$ at about $j = 50$. This would be explained if the molecular contribution typified by "M" was different according as its rotation was in the same or opposite sense to 2A.

Thus, if for one direction "M" was replaced by "$M + 2A_{j=50}$," we should then have the third component merging with the second at $j \doteq 50$. We see this from fig. 4, since displacing the lower curve downwards by about 0·4 units would *roughly* restore symmetry. The above assumption, however, is difficult to account for physically, and doubtless there are other factors which will need consideration ultimately.

X. *The Vibrational States of the Molecule.*

The assignment of vibrational quantum numbers (n' for the initial and n'' for the final state) is given in Table XIII. The data presented are the observed wave-length of the head, the value of ν_0 as determined from experimental data, and the value calculated

TABLE XIII.—Values of [λ Head, ν_0 Obs., ν_0 Calc.]

n'' \ n'	0.	1.	2.	3.	4.	5.	6.	7.
0	5165·22 19373·97 19373·87	5635·53 17755·66 17755·66	6191·21 16160·78 16160·79	14589·26	13041·07	11516·22	10014·71	8536·54
1	4737·08 21127·81 21127·94	5129·34 19509·73 19509·73	5585·49 17914·86 17914·86	6122·07 16343·27 16343·33	14795·14	13270·29	11768·78	10290·61
2	4382·48 — 22843·31	4715·23 — 21225·10	5097·66 — 19630·23	5540·68 — 18058·70	6059·68 — 16510·51	6677·31 — 14985·66	13484·15	12005·98
3	24519·98	4371·43 — 22901·77	4697·60 — 21306·90	19735·37	5501·91 18187·15 18187·18	6004·88 16662·47 16662·33	6599·25 — 15160·82	13682·65
4	26157·95	24539·74	4365·165 — 22944·87	4684·78 — 21373·34	19825·15	5470·28 — 18300·30	5958·7 — 16798·79	6533·68 — 15320·62
5	27757·22	26139·01	24544·14	22972·61	4678·59 — 21424·42	19899·57	18398·06	5923·42 — 16919·89

Note.—The values of ν_0 are for the middle components of the triplets.

from equation (19). Some difficulty was encountered in obtaining satisfactory values of ν_0 for the different bands. It was due firstly to the complexity of the triplet structure, together with the distribution of intensity among the rotational states, which, as we have previously seen, has made accurate measurements of P(1) to P(17) impossible.

In the case of the Swan bands this is particularly unfortunate, as we have already mentioned that the rotational energy function probably contains a term in j^{-1} corresponding to a finite σ, and this assumes importance for small values of j. The staggering of the alternate lines is also a further cause of trouble. It is thought, however, that the following expression is a fairly good representation of the null lines (ν_0) :—

$$\nu = 19373\cdot87 + n' (1773\cdot42 - 19\cdot35n') - n'' (1629\cdot88 - 11\cdot67n'') \quad . \quad . \quad . \quad . \quad . (19)$$

where n' ranges from 0 to 5 and n'' from 0 to 8. The final vibrational function is probably much more reliable than the initial function, as null lines could only be located for a short range of n'. This will be seen from Table XIII. The range of final vibrational states in band spectra is usually greater than that of the initial states, consequent upon the tendency of negative values of $\Delta n = n' - n''$ to preponderate. This is so in the above case (see also fig. 6). The frequency of nuclear vibrations is given by $\omega_n = \frac{1}{h}\frac{dE_n}{dn}$, so that these are respectively in the initial and final electronic states

$$\left.\begin{array}{l}\omega_{n'} = 1773\cdot42 - 38\cdot70n' \\ \omega_{n''} = 1629\cdot88 - 23\cdot34n''\end{array}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (20)$$

It will be noted that while the field of force between the nuclei is stronger in the initial (excited) state, it departs from a harmonic character more rapidly. Using the data for the final electronic state, we see that the molecule would be on the point of dissociation for $n'' = 69$, assuming that the linear relation between ω_n and n holds with sufficient accuracy. Substituting the calculated value $n'' = 69\cdot832$ in the final vibrational function we obtain for the corresponding vibrational energy 56908·89 wave-number units (= 7·02 volts). Using the initial data, and making the same assumptions, we find dissociation at $n' = 45\cdot825$, which gives upon substitution a vibrational energy of 40633·48 units. To this must be added the electronic energy 19373·87 units, giving 60007·35 units = 7·41 volts. The value 7·02 volts from the final data is probably more reliable. Expressed in heat units this is 161,640 calories. Unfortunately we do not know whether the final state of the Swan emitter is the ground level of the molecule (see, however, Section XIII, HORI's work). If so, then the heat of dissociation of the molecule,* presumably into two CH groups, should be of the order 162,000 calories. Otherwise there will be an electronic term to add to this. As far as the writer is aware, there are no known band spectra which have electronic states in common with the Swan spectrum, and it is therefore impossible to deduce anything in this connection. *Most* band spectra (21) which are produced in flames probably have the final electronic state as the normal one, but it is impossible to infer anything with certainty with reference to the Swan bands. If the spectrum does represent a transition from an excited to the normal

* The general theory has been worked out recently by BIRGE and SPONER in an interesting paper entitled "The Heat of Dissociation of Non-Polar Molecules" (not yet published). The writers discuss N_2, NO, O_2, and CO. I am indebted to them for a preliminary copy, which I would like gratefully to acknowledge here.

state, then the bands λ 5165, λ 4737, λ 4382 should appear in absorption in cold acetylene gas (since we believe a C_2H_2 molecule is the emitter). I have been unable to find any evidence of these at all. HENRI and LANDAU (22), however, record a large number of bands in the ultra-violet absorption spectrum of acetylene. I have made a close examination of these, but it is clear that they do not bear any relation to the Swan bands. We have, therefore, practically no knowledge of the electronic energy levels of the HC–CH molecule, except such as we may infer by a comparative study with similarly constituted molecules (see Section XIII).

Mutual Action between Rotation and Oscillation.—At this stage attention may perhaps be drawn to this feature, which is illustrated by the data of Table IX. According to theory, (23) an expression for the total energy of an excited molecule involves not only the purely vibrational and rotational terms, but also a term due to their mutual influence. This involves adding to the energy expression a term of the form $-m^2a_nh$, or it is simply accounted for by writing instead of $A' = h/8\pi^2I'$ the term $h/8\pi^2I' - a_{n'}$, and instead of $h/8\pi^2I''$ the term $h/8\pi^2I'' - a_{n''}$. To a first approximation we may regard the correction as linear, and write $a_{n'} = \alpha'n'$ and $a_{n''} = \alpha''n''$. In Table IX these facts are illustrated: A'' diminishes as n'' increases and A' diminishes as n' increases. Approximately I have estimated $\alpha' = 0\cdot03$, $\alpha'' = 0\cdot025$. As a consequence, $C = A' - A'' = (h/8\pi^2I' - h/8\pi^2I'') - (0\cdot03n' - 0\cdot025\,n'')$ shows a decrease as n' increases, an increase as n'' increases, and a slight decrease as we travel along a sequence $\Delta n =$ a constant.

A little consideration shows that theoretically we should expect an increase in I when vibration of the nuclei sets in. For the effect of oscillation will be to cause each nucleus to travel in an undulating path instead of a circle, and a time average of the square of the distance between the nuclei (upon which I depends) will necessarily be greater than in the vibrationless state.

XI. *The Energy Distribution amongst the Vibrational and Rotational States.*

Fig. 6 shows the vibrational transitions which yield bands of the Swan spectrum. The figures give an estimate of the photographic intensity of each band head. Diagrams of this convenient type have been used by MULLIKEN (18), (24) in connection with the band spectra of BO, CuI, etc. The various sequences $\Delta n = n' - n'' =$ constant, are given by the dotted diagonals. An estimate of the probability of the various initial states is obtained by adding up the intensities under a given value of n'. It would seem that the maximum occurs about $n' = 1$, and that there is a gradual falling off for higher values. As regards the distribution of intensities with respect to Δn, there is a fair degree of symmetry, with a marked tendency towards negative values (which is a feature of most band spectra). Another notable feature is the tendency of transitions either to small or large values of n'' as n' increases. The same thing is found in the A bands of Copper Iodide, and in the α bands of BO two spectra already mentioned.

It is not yet possible to give a full theoretical treatment of the probability of various vibrational states and transitions. It is customary, however, to classify intensity distributions on an experimental basis as characteristic of high and low temperature, and as thermal and non-thermal. Typical low temperature distributions exhibit a strong $n' = 0$ sequence, with a rapid fall off for $n' = 1, 2$, etc.—*e.g.*, the second positive Nitrogen bands, the Aluminium Oxide bands, the Ångström bands, etc. High temperature distributions exhibit a small intensity decrement, or may actually show an increase outwards of n' and a maximum at some distance from the origin—*e.g.*, the ultra-violet

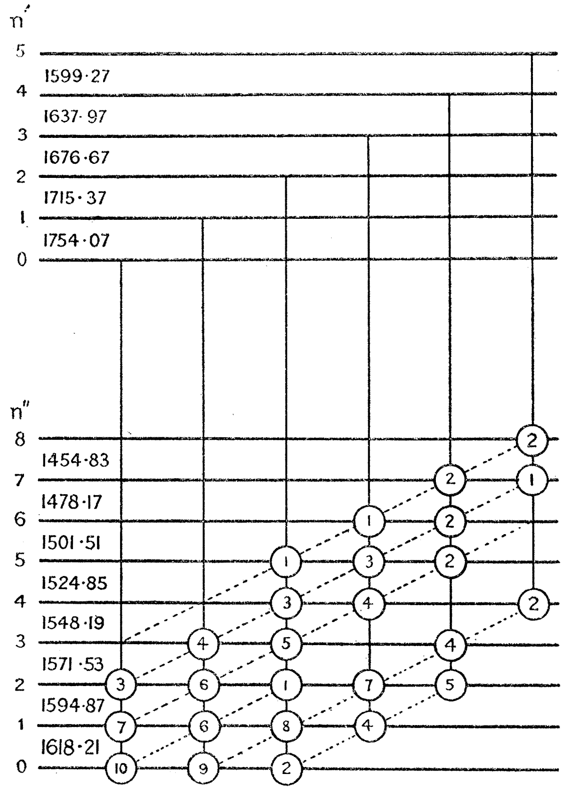

FIG. 6.

O_2^+ bands, the β bands of NO, etc. These latter are necessarily non-thermal in their origin, though for convenience they are described as high temperature distributions.

We may apply these ideas to make a closer study of the Swan band intensities. It is a matter of observation that the intensity distribution among the vibrational states does not appear very different, whether the development is in a tube (at a low temperature) or in a high temperature arc. The sequences are, however, somewhat more extensive under low temperature conditions.

Theory indicates that the probability of a molecule having vibrational energy E_n, say, will be proportional to $e^{-\frac{E_n}{kT}}$: $k = 0 \cdot 698$, and T = absolute temperature. Let us take approximately for the initial state, $E = 1773n$. Then if $T = 373°$, say, the factor is $e^{-6 \cdot 812n'}$, and the probabilities of 0, 1, 2, etc., quanta of vibration are as $1 : 0 \cdot 0011$:

0·000001, etc. If T = 4000°, the factor is $e^{-0\cdot6352n}$, and the probabilities are as 1 : 0·5296 : 0·2807 : 0·1487 : 0·0788 : 0·0417. If the distribution was thermal, we should expect in the tube production to find only the $n' = 0$ sequence, which is far from being the case. Under arc conditions the intensity fall certainly approximates to theory and it *may* be thermal in origin. The Swan bands may therefore be described as a high temperature distribution, non-thermal under the tube conditions.

In connection with the development of the various band heads in an Argon tube, an interesting phenomenon was noticed. Hydrogen was admitted through the regulator of the tube to such a point that the Swan bands were brilliant along the capillary portion, while the " Triplet System " was dominant in the wider side tube into which the capillary merged. An examination of the pale green glow a little outside the capillary (where Swan molecules were presumably radiating surrounded by an excess of " Triplet System " molecules) shows a peculiar development of the 5635 Swan group. Whereas under normal circumstances the estimated intensities of the heads are 7, 6, 5, 4 and 2, under these special conditions the first two heads are dominant, and the others almost invisible. Photographs of this phenomenon were taken, but were not satisfactory owing to the difficulty of keeping the tube exactly in the required condition. It is believed, however, that it is quite genuine, and not a general intensity reduction of the group. Photographs of the system through a neutral wedge would doubtless definitely settle the question.

The energy distribution among the *rotational* states is, however, entirely governed by considerations of temperature, since there is under normal conditions in any gas a statistically permanent distribution of angular velocities. KEMBLE (25) has shown (neglecting the slight variation of I with m owing to centrifugal distension of the molecule) that the value of m corresponding to maximum rotational energy is

$$m_{(\max.)} = 2\pi/h\sqrt{k\mathrm{IT}}, \text{ where } k = \text{BOLTZMANN's Constant} = 1\cdot372 \times 10^{-16} \text{ ergs.}$$

This may be written more conveniently

$$\mathrm{T} = 1\cdot431\ (2\mathrm{A})m^2_{(\max.)}, \quad \text{where } 2\mathrm{A} = h/4\pi^2\mathrm{I}.$$

The values of 2A for the Swan bands are given in Table IX.

An examination of arc plates of several bands shows a maximum intensity in both branches at, roughly, $m = 38 \pm 2$. This corresponds to T = 7000° ± 1000° C. approximately. The intensity maximum in the tube development can be determined with more precision for the R branches. It occurs at about R(12), corresponding to $m = 12\frac{1}{2}$ for the initial state. The corresponding temperature is 762 abs., or, say, 500° ± 150° C. This is a very reasonable value for thermal equilibrium, as the tube, during continuous running, became very hot owing to the heavy current which was passing through it. Such comparatively low temperature distributions of rotational energy appear to be characteristic of the development of spectra in excess of high pressure Argon, and, as already mentioned (20), there is considerable analogy between these conditions and those of production in active Nitrogen.

XII. *A new Band Spectrum associated with the Swan Bands.*

RAFFETY (26) records a number of new bands which he found accompanied the Swan spectrum under certain conditions of production. Under the conditions described in the present paper these did not appear to be present: they were not, however, specially searched for. A quite different system has, however, invariably been found to accompany the Swan spectrum; it has probably escaped detection previously on account of its faintness. The strongest head would probably be of intensity (1) if we take the 5165 Swan band as (10). As far as the writer is aware, the system is new. There is only one pronounced sequence, presumably the $\Delta n = 0$ group; all the others have to be closely searched for, and in many cases they are confused with Swan band structure. For this reason the wave-lengths are not likely to be very accurate. The data, including a tentative assignment of vibrational quantum numbers are given in Table XIV. As the first differences of the wave-numbers are only approximate, a comparison of these with the corresponding values for the Swan bands is not conclusive. The present evidence, however, indicates that neither the initial or final states of the two systems are related. The bands are degraded towards the red side. The strongest bands have a faint head on the more refrangible side of the above. (These are not recorded in Table XIV.) It

TABLE XIV.

Wave-Length. (I.A.).	Int.	ν (Vacuo).	n'.	n''.
6923	0	14441	0	4
6334	1	15783	1	4
6217	3	16080	0	3
5982	2 ?	16712	3	5
5868	2*c*	17038	2	4
5758	2	17361	1	3
5670·3	2	17631	0	2
5195	0	19246	0	1
4996·8	2	20007	3	3
4911·9	4	20353	2	2
4836·2	6	20672	1	1
4770·0	8	20958	0	0
4438	0*c*	22526	1	0

seems possible, therefore, that the measured head is really a well-developed Q branch. The relationship of this system to the Swan bands may possibly be similar to that of the so-called "Tail" bands of Cyanogen to the violet CN bands. To label the spectrum thus is not, however, to provide an explanation of it. A photograph of the strongest head at λ 4770 was obtained in the second order of a 21-foot grating. Under this dispersion it proved to be of an exceedingly complex structure, with no obvious regularities. Its fine structure analysis was therefore not attempted, though it may ultimately be desirable in order to ascertain if its carrier has the same Moment of Inertia as that of the Swan emitter. In the next section a comparison is made between the HC–CH molecule and the N_2 molecule, which are probably very similar. If the HC–CH molecule is capable of a number of electronic levels such as are known to occur in N_2 (27), then it is likely that a natural place will ultimately be found for this new system in the scheme.

XIII. *The Nature of the Swan Band Emitter.*

The evidence already presented, which has been derived from an analysis of the spectrum, points strongly to a CH–HC molecule as the emitter. The moment of inertia and the resulting size of the molecule are such as we might expect by comparison with other molecules of about the same mass and electron structure. To the N_2 molecule the analogy should be very close, for this has the same number of electrons—viz., 14—which are presumably arranged in a similar manner. Plate 4 No. 6 is a photograph of the (0, 0) band of the second positive Nitrogen system, and even a casual glance reveals a remarkable similarity to the Swan structure of No. 5. This in itself is very convincing. Further, the absence of a Q branch indicates a high degree of symmetry in the molecule, since it indicates a pure rotational motion. This would be accounted for by a HC–CH structure in which the CH group is effectively one nucleus. Whether any internal oscillation of this group is possible is conjectural. It seems unlikely, for the binding of the CH group is probably a very close one in the Swan molecule, and dissociation of the latter into two CH groups would be the easier alternative in that case.

A discussion of the experimental evidence seems, however, desirable, especially as different observers have arrived at very different results and conclusions. On the basis of experimental work some observers (28) have, for example, assigned the system to CO. In addition, the relationship between the Swan bands and the CH bands (λ 4315, etc.) is of importance, as it is generally admitted that the latter have a hydrocarbon origin.

The suggestion of a CO origin will first be considered. It is well known that the discharge through imperfectly dried CO or CO_2 will yield the Swan spectrum. For example, a photograph by Fowler (29) of the discharge through CO shows the system strongly, although the CH band and Hα are not visible. Baly (28), writing in 1892, describes the preparation of pure CO from formic acid and sulphuric acid, and states that a discharge through pure CO gives the Swan spectrum (and not the Ångström bands). Admixture of a little Oxygen is stated, however, to destroy the Swan and substitute the Ångström bands. Smithells (28) arrives at the same results as Baly, and attributes the Swan bands to CO and the Ångström bands to CO_2.

With regard to the Ångström bands we now know quite definitely that they originate in a neutral CO molecule by a transition of the valence electron from a 2S to a 1P orbit. Its relations to the other spectra of the neutral CO molecule are known precisely (30), and the energy levels suggested by Birge and the author have been confirmed by

DUFFENDACK and FOX (31). To HULTHEN (32) we are indebted for a fine structure analysis of the bands, and this and other evidence confirms the diatomic character of the emitter. With regard to the production of the Swan bands from CO, it must be emphasised that the elimination of at least a trace of Hydrogen under discharge conditions is (as mentioned on page 158) an exceedingly difficult matter. In spite of every precaution to ensure complete purity and dryness of the gas, and cleanliness of the discharge tube, it is the writer's experience that the passage of a discharge usually produces some Hydrogen, probably from the glass walls of the tube. The writer has found that to completely remove Hydrogen it is usually necessary to attach to the discharge tube small side bulbs of potassium permanganate and phosphorus pentoxide, respectively. Prolonged running of the tube with frequent admission of Oxygen can usually be relied on to remove all Hydrogen as water into the P_2O_5. Granted then the possibility of some Hydrogen in the CO under the discharge conditions used by these workers, the appearance of the Swan bands is not unexpected. For if, as seems likely, the Swan bands are the resonance system of the molecule, the excitation potential of the (0, 0) band will be 2·39 volts, which is considerably lower than that of the 4th positive bands (7·99 volts), and than that of the Ångström bands (10·72 volts). This should favour the production of the Swan system.

Further, there is more recent experimental evidence which is in definite contradiction to those workers who maintain that the Swan bands can be obtained from pure CO. In particular, BALDET (33) prepared very pure CO, and bombarded it with 100-volt electrons in a thermionic bulb. He observed the Ånsgtröm bands, the 3rd positive bands, the negative carbon bands, and the Comet-Tail and associated bands, all of which we know to arise from CO and CO^+ molecules. He specifically states, however, that "in spite of the intensity of emission, one could find no trace of the Swan group or of the so-called CH group." Against a CO origin for the Swan bands is also the knowledge we have of the CO molecule. Six electronic levels of the neutral molecule have been recognised, viz., 1S, $1p_{123}$, 1P, 1s, 2S, and 2d, corresponding to the normal level and the initial levels of the Cameron bands, the 4th positive bands, the 3rd positive bands, the Ångström bands, and the 3A bands respectively. It is unlikely that the Swan bands should arise in any higher level than these, but even if they could, then they should have their final level common with one of the above-mentioned electronic levels. I have made an investigation of all likely Carbon band spectra, and in no case does the Swan system have a level in common. DUFFENDACK and FOX (31), using pure CO under electronic bombardment, have confirmed the above scheme of levels, and they record no excitation potential appropriate to the Swan bands.

One further piece of experimental evidence* is worth recording, viz., the phenomena of the relative intensity variations of the Swan bands and the CH bands in the coal-gas air flame. The phenomena are well illustrated in a Mecker burner. With admission of a certain quantity of air the cone has a pronounced green colour, but increasing the

* I am indebted to Prof. MERTON for pointing this out to me.

quantity of air beyond a definite amount changes this to an equally pronounced blue colour. These changes correspond to a diminution in the strength of the Swan system, and an increase in that of the CH bands when the Oxygen supply is increased. Now the CH bands have admittedly a hydrocarbon origin, and if the Swan bands originate in CO then the above observation admits of no satisfactory explanation. But if the Swan bands arise from C_2H_2 and the " CH " bands from a simple CH molecule, as the writer believes, a natural explanation follows from the increased tendency to dissociation of the former molecule in the hotter flame.

Turning now to the positive evidence in favour of a hydrocarbon origin for the Swan bands, we have the experimental observation recorded in Section II. Only Pure Hydrogen can be admitted by heating the Palladium regulator of such a tube. The fact that the tubes used were furnished with side bulbs containing caustic potash and phosphorus pentoxide, respectively, and in some cases had been run for hundreds of hours, eliminates any doubt as to their complete freedom from Oxygen. The Swan bands were therefore produced with intense brilliance in the presence of high pressure Argon, with *only* Carbon and Hydrogen present, and the admission of Hydrogen was *necessary*, otherwise the tube " cleaned up," leaving only the continuous and a little of the red spectrum of Argon.

WATTS (34) describes a number of experiments in which the possibility of Oxygen contamination was probably eliminated. These consisted in examining the spectrum of a minute spark under the surface of various carefully distilled hydrocarbons contained in a fluorspar vessel, the vessel being evacuated. Heptane, hexane, octane, etc., all yielded brilliant Swan spectra. Under these conditions we really have a discharge in a small vapour-filled cavity of which the walls consist of the liquid itself, and the results seem to admit therefore of only one interpretation. KONEN (35) has similarly obtained the Swan bands in the arc burned under various liquids, but in this case the possibility of contamination is appreciable.

Interesting evidence of a very different character is forthcoming in some experiments of HORI (36). He has examined the spectra of exploded threads of Mercury, using ANDERSON's method, and reports that " under reduced pressure the Swan bands appear in absorption by this process owing to the presence of oil in the explosion chamber." (The exploded Mercury thread provides a continuous spectrum.) This result is interesting for two reasons: (1) It indicates that the Swan bands are probably the resonance system since they occur in absorption, and (2) it points to a hydrocarbon origin.

Granted the hydrocarbon origin of the Swan bands, the fine structure analysis indicates that two Carbon atoms are present. The singlet character of the levels definitely classes the Swan emitter as an even-valence electron molecule, which means that 2, 4, etc., Hydrogen atoms may be present in the molecule. The close analogy to the 2nd positive Nitrogen bands, which arise from a neutral N_2 molecule with 14 electrons, point to its origin in a CH–HC molecule which would also have 14 electrons.

It now remains to consider the degree of association of the Swan and the CH bands under various experimental conditions. In view of the hydrocarbon origin of both these systems, some measure of association may be expected. I have made a few approximate calculations from a second order plate taken on the 21-foot grating of the λ 4315 CH band, and I find for the moment of inertia of the emitter $I \doteqdot 1 \cdot 80 \times 10^{-40}$, corresponding to an internuclear distance d of about $1 \cdot 09 \times 10^{-8}$ cm. if we assume a CH molecule. This is in good agreement with the order of molecular sizes. Even the assumption of a CH_2 group would give d a highly improbable value, and we may put considerable confidence in the above result. A highly unsymmetrical molecule such as CH is quite in harmony with the nature of the λ 4315 and other bands which exhibit Q branches and other complications. As the Swan and the CH bands arise from different emitters we should expect—and experiment confirms—that under different conditions of production the relative intensities of the two spectra will vary considerably. Unfortunately we do not know anything about the excitation potential of the CH bands. The relative intensities of the two systems may, however, be expected to depend on the extent to which the C_2H_2 molecule is dissociated into CH molecules under given conditions. (An excellent discussion of the mechanism of molecular dissociation has been given by Franck (37).) We may therefore reasonably expect more energetic conditions of production to increasingly favour the CH bands. This was previously noted in the case of the coal-gas flame. I have observed that in general the production of these spectra, in the presence of high pressure Helium, Argon, or Neon with an uncondensed discharge gives a dominant Swan spectrum with the CH bands weak. Such, as we have seen, are mild low temperature conditions of production. In spectrum No. 1 of the present paper both the Swan and the CH bands are strong. In this case the conditions of production were somewhat intermediate between those just mentioned and an ordinary heavy capillary tube discharge, viz., a discharge through a high pressure Argon tube (containing Carbon and Hydrogen), but with a very heavy current.

The association of the CH bands with the Balmer Series is noteworthy. The appearance of the latter would be expected as a consequence of dissociation of the CH molecule. It may be mentioned that after prolonged running of the above Argon tube, dense films of fine Carbon were deposited. Dissociation of the CH molecule is probably not difficult, for the curiously isolated character of the few known bands (and the different directions in which they are degraded) suggests that they arise in different *electronic* states of the CH molecule, which is not sufficiently stable to admit of much vibration (*cf.* the Helium doublet bands).

Reverting to the Swan bands, there is cumulative evidence pointing to their origin in a HC–CH molecule. On the basis of recent classifications of band spectra the above would be a 2-valence electron emitter similar to N_2, CO, etc. It is suggested that the structure of the molecule is probably as follows. Each Carbon atom retains its K electrons, which will be shared by the CH group and move in 1_1 orbits. Common to the whole molecule will then be the complete L shell of the four 2_1 electrons and four 2_2 electrons, and finally, outside (but penetrating to between the nuclei), will be the two valence electrons in 3_1 orbits. The ground level will be 1S as in the magnesium atom. It follows from the recent views of BIRGE (38) that we may then expect the valence electron of the HC–CH molecule to be capable of a number of singlet and triplet levels as in the "corresponding" atom of magnesium.

Further evidence is found in an invariable relation* between the Moment of Inertia and the frequency of nuclear vibrations, discovered by BIRGE and MECKE. For molecules such as hydrides, the products $I\omega$ are usually about 7,000, while for molecules like N_2, CO, NO, O_2, etc., the products $I\omega$ are about 30,000. For the Swan bands the data of the green head give the product as 28,800, which indicates that the emitter is of the latter type. A HC–CH emitter, therefore, seems to be finally established.

I would like in conclusion to draw attention to the work of BIRGE and SHEA (39) on the Swan spectrum, of which only preliminary results have been published so far. I am especially grateful to Prof. BIRGE for his courtesy and generosity in several communications with reference to this work, and I would like to tender to him my very best thanks.

XIV. *Summary.*

(1) An extensive survey of the so-called Swan band spectrum has been made. For purposes of the analysis of its fine structure the spectrum has been photographed in the second order of a 21-foot grating, and the wave-lengths of about 2,000 lines are recorded.

(2) Series assignments have been made in the case of 11 bands. Details of the evaluation of the rotational energy functions are given, and full applications of the graphical method of determining moments of inertia with formulæ. From the second components of the triplets for the λ 5165 head, we have $I' = 16 \cdot 236 \times 10^{-40}$ and $I'' = 17 \cdot 410 \times 10^{-40}$, giving for the internuclear distances before and after the transition $1 \cdot 230 \times 10^{-8}$ cm. and $1 \cdot 274 \times 10^{-8}$ cm. These are appropriate to a HC–CH molecule.

(3) The application of the combination principle to the data of several of the bands is considered. A number of alternative explanations of the band structure are examined. It was finally decided that the bands consist each of a P and R branch typical of a di-polar emitter.

(4) The bands exhibit several anomalous features, perturbations, etc., and these have been examined and discussed.

(5) The fine structure multiplicity classes the bands as of the Heurlinger Triplet type. Certain theoretical views are put forward tentatively.

(6) The distribution of energy among the rotational and vibrational states is examined, and as regards the latter the Swan bands are a high temperature, but probably non-thermal system.

(7) A new band system associated with the Swan bands is recorded.

(8) The evidence both of direct experiment and of analysis is conclusive in assigning the Swan bands to a HC–CH molecule.

* I am indebted to Prof. BIRGE for informing me of this relation.

TABLE I.

λ (I.A.).	Int. (Tube).	Int. (Arc).	ν (Vacuo).	Series.
5165·219	10	10	19354·89	P_1 (16), P_1 (15)
65·102	10	10*c*	355·32	P_1 (17), P_2 (16)
64·992	10	10	355·74	P_2 (17)
64·918	conf.	?	356·01	P_1 (18), P_3 (17)
64·872	10	10*vc*	356·19	P_1 (11), P_2 (18)
64·758	10	7	356·61	P_2 (11), P_3 (18)
64·643	8	6	357·05	P_1 (19)
64·531	8	6	357·47	P_2 (19)
64·462	8	6	357·72	P_3 (19)
64·360	9	6	358·12	P_1 (20)
64·253	8	6*d*	358·51	P_2 (20)
64·176	3	6*d*	358·81	P_3 (20)
64·109	4	—	359·05	P_3 (9) ?
63·973	6	4*d*	359·56	P_1 (21)
63·916	7*c*	—	359·76	P_1 (8) ?
63·857	2	2	359·99	P_2 (21)
63·783	3	2	360·27	P_3 (21)
63·693	5	—	360·61	P_3 (8) ?
63·577	9	9*d*	361·04	P_1 (22)
63·519	9	—	361·26	P_2 (22)
63·398	7*d*	9*d*	361·71	P_3 (22)
63·142	7*d*	—	362·67	P_3 (7)
63·030	8	6	363·09	P_1 (23)
62·912	4	5	363·54	P_2 (23)
62·848	4	5	363·78	P_3 (23)
62·539	10*d*	5	364·93	P_1 (24)
62·338	9*d*	7	365·69	$P_{2,3}$ (24)
61·815	3	3	367·65	P_1 (25)
61·712	4	3*d*	368·04	P_2 (25)
61·653	4	3*d*	368·26	P_3 (25)
61·343	3	—	369·42	
61·255	3	—	369·75	
61·142	3	4	370·17	P_1 (26)
61·016	5	7*d*	370·65	$P_{2\ 3}$ (26)
60·837	1	—	371·32	
60·694	3	—	371·86	
60·546	3	—	372·41	
60·358	4	3	373·12	P_1 (27)
60·251	3	—	373·52	P_2 (27)
60·190	5	4*d*	373·75	P_3 (27)
59·568	4	5	376·09	P_1 (28)
59·435	6*d*	8	376·58	$P_{2,3}$ (28)
58·874	3*c*	—	378·69	
58·637	4	4	379·58	P_1 (29)
58·504	8*c*	6	380·08	$P_{2,3}$ (29)
58·344	4	—	380·68	
58·175	3	—	381·32	R_2 (2) ?
58·030	1	—	381·86	R_1 (3)
57·931	2	—	382·23	
57·728	3	4	383·00	P_1 (30)
57·601	6*d*	8	383·47	$P_{2,3}$ (30)
57·141	3	—	385·20	R_2 (3)
56·758	3	—	386·64	R_1 (4)
56·658	1	4	387·02	P_1 (31)
56·537	3	6	387·47	$P_{2,3}$ (31)

Table I (continued).

λ (I.A.).	Int. (Tube).	Int. (Arc.)	ν (Vacuo).	Series.
5156·084	6*d*	—	19389·18	R_3 (3), R_2 (4)
55·627	0	4	390·90	P_1 (32)
55·563	4	—	391·14	R_1 (5)
55·496	3	8	391·39	$P_{2,3}$ (32)
55·171	8	—	392·61	R_3 (4)
54·969	8	—	393·37	R_2 (5)
54·419	0	4	395·44	P_1 (33)
54·302	0	6	395·88	$P_{2,3}$ (33)
54·204	8	—	396·25	R_1 (6)
54·148	9	—	396·46	R_3 (5)
53·748	10	—	397·97	R_2 (6)
53·269	0	4	399·77	P_1 (34)
53·143	1	8	400·24	$P_{2,3}$ (34)
53·049	10	—	400·60	R_3 (6)
52·933	9	—	401·035	R_1 (7)
52·482	9	—	402·73	R_2 (7)
51·927	0	4	404·82	P_1 (35)
51·876	9*vc*	—	405·01	R_3 (7)
51·812	0	7*d*	405·25	$P_{2,3}$ (35)
51·495	10	—	406·45	R_1 (8)
51·143	10	—	407·78	R_2 (8)
50·645	0	4	409·66	P_1 (36)
50·625	10	—	409·73	R_3 (8)
50·532	0	8	410·08	$P_{2,3}$ (36)
50·113	10	—	411·66	R_1 (9)
49·758	10	—	413·00	R_2 (9)
49·303	10	—	414·71	R_3 (9)
49·186	0	3	415·15	P_1 (37)
49·065	1	6*d*	415·61	$P_{2,3}$ (37)
48·583	10	—	417·43	R_1 (10)
48·299	10	—	418·50	R_2 (10)
47·902	10	—	420·00	R_3 (10)
47·792	1	3	420·41	P_1 (38)
47·673	1	8	420·86	P_{23} (38)
47·090	10	—	423·06	R_1 (11)
46·791	10	—	424·19	R_2 (11)
46·444	10	—	425·50	R_3 (11)
46·183	0	3	426·48	P_1 (39)
46·069	1	7	426·91	P_{23} (39)
45·450	10	—	429·25	R_1 (12)
35·210	10	—	430·16	R_2 (12)
44·899	10	—	431·33	R_3 (12)
44·662	0	3	432·22	P_1 (40)
44·551	1	8	432·64	P_{23} (40)
43·846	10	—	435·31	R_1 (13)
43·578	10	—	436·32	R_2 (13)
43·307	10	—	437·34	R_3 (13)
42·933	0*c*	3	438·76	P_1 (41)
42·817	0*c*	6	439·20	P_{23} (41)
42·092	10	—	441·94	R_1 (14)
41·877	10	—	442·75	R_2 (14)
41·626	10	—	443·70	R_3 (14)
41·295	0	3	444·95	P_1 (42)
41·187	0	8	445·36	P_{23} (42)
40·363	10	—	448·48	R_1 (15)

Table I (continued).

λ (I.A.).	Int. (Tube).	Int. (Arc).	ν (Vacuo).	Series.
5140·122	10	—	19449·39	R_2 (15)
39·911	10	—	450·19	R_3 (15)
39·424	—	3	452·03	P_1 (43)
39·317	0	5	452·43	P_{23} (43)
38·493	10	—	455·56	R_1 (16)
38·296	10	—	456·30	R_2 (16)
38·094	10	—	457·07	R_3 (16)
37·672	—	3	458·66	P_1 (44)
37·566	0	7	459·06	P_{23} (44)
36·640	10	—	462·57	R_1 (17)
36·426	10	—	463·38	R_2 (17)
36·256	10	—	464·03	R_3 (17)
35·672	—	2	466·24	P_1 (45)
35·561	0	5	466·66	P_{23} (45)
34·654	9	—	470·10	R_1 (18)
34·472	9	—	470·79	R_2 (18)
34·300	9	—	471·44	R_3 (18)
33·802	—	2	473·33	P_1 (46)
33·696	—	7	473·73	P_{23} (46)
32·681	9	—	477·58	R_1 (19)
32·481	9	—	478·31	R_2 (19)
32·343	9	—	478·87	R_3 (19)
31·675	0	2	481·40	P_1 (47)
31·573	0	5	481·79	P_{23} (47)
30·563	9	—	485·63	R_1 (20)
30·400	9	—	486·25	R_2 (20)
30·255	9	—	486·80	R_3 (20)
29·682	—	2	488·97	P_1 (48)
29·582	—	6	489·35	P_{23} (48)
29·337*	9	—	490·28	P_1' (16), P_1' (14)
29·209	9	—	490·77	P_1' (17), P_2' (16)
29·097	10	—	491·19	P_1' (18), P_2' (17)
28·962	8	—	491·71	P_2' (18), P_3' (17)
28·832	8	—	492·20	P_1' (19), P_3' (18)
28·718	4	—	492·63	P_2' (19)
28·585	6	—	493·14	P_1' (20), P_3' (19)
28·476	6	—	493·55	R_1 (21), P_2' (20)
28·404	4	—	493·83	P_3' (20)
28·294	8	—	494·25	R_2 (21)
28·175	8	—	494·70	R_3 (21), P_1' (21)
28·052	4	—	495·16	P_2' (21)
27·956	3	—	495·53	P_3' (21)
27·855	1	—	495·92	
27·750	3*d*	—	496·32	P_1' (22)
27·653	4	—	496·69	P_2' (22)
27·557	4	—	497·05	P_3' (22)
27·382	1	—	497·72	
27·257	4	—	498·19	P_1' (23)
27·180	4	—	498·48	P_2' (23)
27·096	3	—	498·80	P_3' (23)
26·871	1	—	499·66	
26·704	4	—	500·29	P_1' (24)
26·603	4	—	500·68	P_{23}' (24)
26·245	8	—	502·04	R_1 (22), P_1' (25)
26·069	8*c*	—	502·71	R_2 (22)

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Table I (continued).

λ (I.A.).	Int. (Tube).	Int. (Arc).	ν (Vacuo).	Series.
5126·028	2*d*	—	19502·86	$P_{2,3}'$ (25)
25·961	8	—	503·12	R_3 (22)
25·631	1	—	504·37	P_1' (26)
25·494 }	3*d* }	—	504·90 }	$P_{2,3}'$ (26)
25·432 }	3*d* }	—	505·13 }	
25·277	—	1*c*	505·72	P_1 (50)
25·251	1	—	505·82	
25·221	—	6*c*	505·93	$P_{2,3}$ (50)
24·898	—	—	507·16	P_1' (27)
24·777	2	—	507·62	$P_{2,3}'$ (27)
24·335	0	—	509·31	
24·157	0	—	509·98	P_1' (28)
24·038	8	—	510·44	R_1 (23), $P_{2,3}'$ (28)
23·865	7	—	511·06	R_2 (23)
23·766	7	—	511·48	R_3 (23)
23·299	0	—	513·25	
23·144	0*d*	—	513·84	P_1' (29)
22·852	—	1*c*	514·96	P_1 (51), $P_{2,3}'$ (29)
22·793	—	6*c*	515·18	$P_{2,3}$ (51)
22·600	2	—	515·92	
22·458	1	—	516·46	P_1' (30)
22·292	1*d*	—	517·09	R_1' (3), $P_{2,3}'$ (30)
21·680	6	—	519·42	R_1 (24)
21·531	6	—	519·99	R_2 (24)
21·424	6	—	520·40	R_3 (24)
21·331	0	—	520·75	R_2' (3)
20·998	1	—	522·02	R_1' (4)
20·707	—	1	523·13	P_1 (52)
20·617	—	5	523·47	$P_{2,3}$ (52)
20·598	0*d*	—	523·55	
20·456	0	—	524·09	
20·300	4	—	524·68	R_3' (3), R_2' (4)
19·830	1	—	526·48	R_1' (5)
19·364	7	—	528·25	R_1 (25), R_3' (4)
19·199	6	—	528·88	R_2 (25), R_2' (5)
19·113	5	—	529·21	R_3 (25)
18·817	0	—	530·34	
18·509	2	—	531·51	R_1' (6)
18·400	2	—	531·93	R_3' (5)
18·241	—	3*c*	532·53	P_1 (53)
18·062	—	3*c*	533·22	$P_{2,3}$ (53)
18·034	2	—	533·33	R_2' (6)
17·324	2	—	536·04	R_3' (6)
17·264	2	—	536·27	R_1' (7)
16·876	6	—	537·75	R_1 (26)
16·816	4	—	537·98	R_2' (7)
16·732	6	—	538·30	R_2 (26)
16·638	6	—	538·66	R_3 (26)
16·195	5	—	540·35	R_3' (7)
15·869	4	—	541·59	R_1' (8)
15·856	—	1	541·64	P_1 (54)
15·758	—	5	542·02	$P_{2\ 3}$ (54)
15·515	4	—	542·95	R_2' (8)
14·984	5	—	544·97	R_3' (8)
14·527	4	—	546·72	R_1' (9)

Table I (continued).

λ (I.A.)	Int. (Tube).	Int. (Arc).	ν (Vacuo).	Series.
5114·438	4	—	19547·06	R_1 (27)
14·283	4	—	547·65	R_2 (27)
14·190	6	—	548·01	R_3 (27), R_2' (9)
13·705	6	—	549·86	R_3' (9)
13·196	—	0	551·81	P_1 (55)
13·082	—	5	552·24	$P_{2,3}$ (55)
13·051	6	—	552·36	R_1' (10)
12·760	6	—	553·50	R_2' (10)
12·346	6	—	555·06	R_3' (10)
11·833	4	—	557·02	R_1 (28)
11·703	4	—	557·52	R_2 (28)
11·606	6	—	557·89	R_3 (28), R_1' (11)
11·289	5	—	559·10	R_2' (11)
10·935	6	—	560·46	R_3' (11)
10·752	—	1*vc*	561·16	P_1 (56)
10·665	—	3*c*	561·49	$P_{2\ 3}$ (56)
10·011	6	—	563·99	R_1' (12)
09·759	6	—	564·96	R_2' (12)
09·439	6	—	566·18	R_3' (12)
09·294	5	—	566·74	R_1 (29)
09·143	4	—	567·32	R_2 (29)
09·089	4	—	567·52	R_3 (29)
08·453	5	—	569·96	R_1' (13)
08·180	5	—	571·00	R_2' (13)
07·972	—	1	571·80	P_1 (57)
07·901	5	—	572·07	R_3' (13)
07·872	—	5	572·19	P_{23} (57)
07·618	0	—	573·16	
06·759	5	—	576·45	R_1' (14)
06·536	5	—	577·31	R_1 (30), R_2' (14)
06·432	1	—	577·70	R_2 (30)
06·350	1	—	578·02	R_3 (30)
06·271	5	—	578·32	R_3' (14)
05·434	—	1	581·53	P_1 (58)
05·342	—	4	581·89	P_{23} (58)
05·079	5	—	582·90	R_1' (15)
04·838	5	—	583·82	R_2' (15)
04·613	5	—	584·68	R_3' (15)
03·901	3	—	587·41	R_1 (31)
03·761	3*c*	—	587·95	R_2 (31)
03·717	3*c*	—	588·12	R_3 (31)
03·274	5	—	589·82	R_1' (16)
03·069	5	—	590·61	R_2' (16)
02·857	5	—	591·42	R_3' (16)
02·526	—	0	592·69	P_1 (59)
02·422	—	4	593·09	P_{23} (59)
01·481	5	—	596·71	R_1' (17)
01·263	5	—	597·54	R_2' (17)
01·073	6	—	598·27	R_3' (17), R_1 (32)
00·929	2	—	598·83	R_2 (32)
00·857	2	—	599·10	R_3 (32)
5099·877	—	1	602·87	P_1 (60)
99·774	—	4*c*	603·26	P_{23} (60)
99·561	5	—	604·08	R_1' (18)
99·381	5	—	604·51	R_2' (18)

Table I (continued).

λ (I.A.).	Int. (Tube).	Int. (Arc).	ν (Vacuo).	Series.
5099·199	5	—	19605·48	R_3' (18)
98·284	1	—	609·00	R_1 (33)
98·133	2	—	609·58	R_{23} (33)
97·662*	5	—	611·39	R_1' (19)
97·579	1	—	611·71	P_1'' (17)
97·456	5	—	612·18	R_2' (19)
97·414	0*c*	—	612·34	P_2'' (17), P_1'' (18)
97·306	5	—	612·76	R_3' (19), P_2'' (18)
97·268	1	—	612·90	P_3'' (17)
97·200	1	—	613·17	P_3'' (18), P_1'' (19)
97·069	2*d*	—	613·67	P_{23}'' (19), P_1'' (20)
96·844	—	0	614·53	P_1 (61)
96·801	2	—	614·70	
96·740	—	4	614·94	P_{23} (61)
96·545	1	—	615·69	P_{23}'' (21)
96·361	1*d*	—	616·39	
96·174	1	—	617·11	
95·885	0	—	618·23	
95·761	1	—	618·70	
95·621	2	—	619·24	R_1' (20)
95·457	2	—	619·87	R_2' (20)
95·311	—	6	620·42	R_1 (34)
95·307	4	—	620·45	R_3 (20)
95·264	1*c*	—	620·62	
95·194	1*c*	5	620·88	R_2 (34)
95·134	1*c*	5	621·12	R_3 (34)
94·811	1*d*	—	622·36	
94·250	2*d*	—	624·52	
94·095	—	0	625·12	P_1 (62)
94·002	—	3	625·48	P_{23} (62)
93·615	3*d*	—	626·97	R_1' (21)
93·418	3	—	627·73	R_2' (21)
93·301	3	—	628·18	R_3' (21)
93·023	0	—	629·25	
92·883	0*d*	—	629·79	
92·444	1	5	631·48	R_1 (35)
92·292	2	8*d*	632·07	R_{23} (35)
91·460	3	—	635·27	R_1' (22)
91·291	3	—	635·93	R_2' (22)
91·157	3	—	636·44	R_3' (22)
90·932	—	0*c*	637·31	P_1 (63)
90·833	—	2	637·69	P_{23} (63)
89·661	0	—	642·22	
89·350	—	5	643·42	R_1 (36)
89·345	3	—	643·44	R_1' (23)
89·236	—	5	643·86	R_2 (36)
89·178	—	5	644·08	R_3 (36)
89·162	3	—	644·14	R_2' (23)
89·054	3	—	644·56	R_3' (23)
88·628	0	—	646·24	
88·436	0	—	646·94	
88·231	0	—	647·74	
87·994	—	2	649·65	P_{23} (64)
87·756	0	—	649·57	
87·606	—	—	650·15	

Table I (continued).

λ (I.A.).	Int. (Tube).	Int. (Arc).	ν (Vacuo).	Series.
5087·413	0	—	19650·90	
87·058	2	—	652·27	R_1' (24)
86·915	2	—	652·82	R_2' (24)
86·795	2	—	653·28	R_3' (24)
86·453	1	—	654·61	
86·386	1	5	654·78	R_1 (37)
86·234	2	9*d*	655·45	R_{23} (37)
85·776	2	—	657·22	
85·313	1	—	659·01	
84·819	3	—	660·92	R_1' (25)
84·809	—	0*c*	660·96	P_1 (65)
84·688	—	2	661·43	P_{23} (65)
84·662	3	—	661·53	R_2' (25)
84·563	3	—	661·91	R_3' (25)
84·352	0	—	662·73	
84·051	1	—	663·89	
83·489	1	—	666·07	
83·313	0	—	666·75	
83·169	0	5	667·30	R_1 (38)
83·051	1*vd*	5*c*	667·76	R_2 (38)
83·006	—	5*c*	667·93	R_3 (38)
82·811	0	—	668·69	
82·433	2	—	670·15	R_1' (26)
82·279	2	—	670·75	R_2' (26)
82·185	2	—	671·11	R_3' (26)
81·756	—	1	672·77	P_{23} (66)
81·620	2	—	673·30	
80·954	2	—	675·88	
80·221	0	—	678·71	
80·085	—	6	679·24	R_1 (39)
80·080	2	—	679·26	R_1' (27)
79·946	—	10	679·78	R_{23} (39)
79·938	2	—	679·81	R_2' (27)
79·847	1	—	680·16	R_3' (27)
79·696	1	—	680·75	
79·607	1	—	681·09	R_3'' (11)
78·698	0	—	684·62	
78·431	—	0	685·65	P_1 (67)
78·346	—	1	685·98	P_{23} (67)
78·339	1	—	686·01	R_2'' (12)
78·171	1	—	686·66	R_3'' (12)
77·581	1*d*	—	688·95	R_1' (28)
77·449	1	—	689·46	R_2' (28)
77·368	1	—	689·77	R_3' (28)
77·196	1	—	690·44	
76·870	1	—	691·70	R_2'' (13)
76·762	1	4	692·12	R_1 (40)
76·626	00	7	692·65	R_{23} (40), R_3'' (12)
75·600	1	—	696·63	
75·389	—	1	697·45	P_1 (68)
75·294	—	1	697·82	P_{23} (68)
75·273	2	—	697·90	R_2'' (14)
75·129	1	—	698·46	R_1' (29)
74·987	1	—	699·01	R_2' (29)

Table I (continued).

λ (I.A.).	Int. (Tube).	Int. (Arc).	ν (Vacuo).	Series.
5074·924	1	—	19699·26	R_3' (29)
73·953	1	—	703·02	R_1'' (15)
73·679	1	—	704·09	R_2'' (15)
73·578	—	4	704·48	R_1 (41)
73·453	—	9	704·96	R_{23} (41)
73·442	1	—	705·01	R_3'' (15)
73·111	0	—	706·29	
72·532	1	—	708·54	R_1' (30)
72·420	1	—	708·98	R_2' (30)
72·330	1	—	709·33	R_3' (30)
72·196	1	—	709·85	R_1'' (16)
71·961	1*c*	—	710·76	R_2'' (16)
71·763	—	1	711·53	P_{23} (69)
71·649	1	—	711·98	R_3'' (16)
70·591	0*d*	—	716·09	
70·474	1*d*	—	716·54	R_1'' (17)
70·258	0	—	717·38	R_2'' (17)
70·136	—	4	717·86	R_1 (42)
69·994	—	7	718·41	R_{23} (42)
69·982	2*d*	—	718·46	R_1' (31), R'' (16)
69·779	1	—	719·25	R_{23}' (31)
68·622	1*d*	—	723·75	R_1'' (18)
68·618	—	1	723·76	P_{23} (70)
68·416	1*c*	—	724·55	R_2'' (18)
68·197	1*c*	—	725·40	R_3'' (18)
67·592	0	—	727·76	
67·494	0*d*	—	728·14	
66·845	—	4	730·66	R_1 (43)
66·814	1	—	730·79	R_1'' (19)
66·723	—	8	731·14	R_{23} (43), R_{23}'' (19)
66·343	1	—	732·62	
65·036	—	1	737·71	P_{23} (71)
64·999	0*d*	—	737·85	
64·834	1	—	738·50	R_1'' (20)
64·645	0*c*	—	739·23	R_2'' (20)
64·418	1*d*	—	740·12	R_3'' (20)
63·290	0	3	744·52	R_1 (44)
63·164	0	7*d*	745·01	R_{23} (44)
62·919	0*c*	—	745·96	R_1'' (21)
62·706	0*c*	—	746·79	R_2'' (21)
62·578	0*c*	—	747·29	R_3'' (21)
61·705	—	1*vd*	750·70	P_{23} (72)
60·819	0*c*	—	754·16	R_1'' (22)
60·655	0*c*	—	754·80	R_2'' (22)
60·505	0*c*	—	755·38	R_3'' (22)
59·908	0	3	757·71	R_1 (45)
59·789	0	8*d*	758·18	R_{23} (45)
58·927	—	0	761·53	P_{23} (73)
58·907	0	—	761·62	
58·803	0	—	762·03	R_1'' (23)
58·616	0	—	762·76	R_2'' (23)
58·507	0	—	763·19	R_3'' (23)
56·442	1	—	771·26	R_{23}'' (24)
56·237	—	3	772·06	R_1 (46)

Table I (continued).

λ (I.A.).	Int. (Tube).	Int. (Arc.)	ν (Vacuo).	Series.
5056·116	—	6	19772·53	R_{23} (46)
54·616	—	0*d*	778·40	P_{23} (74)
54·312	1	—	779·59	R_{23}'' (25)
52·743	—	2	785·73	R_1 (47)
52·632	1	7	786·16	R_{23} (47)
50·725	—	0	793·63	
45·346	—	1	814·78	R_1 (49)
45·268	—	6*d*	815·04	R_{23} (49)
41·409	—	3*c*	830·21	R_1 (50)
41·335	—	4*c*	830·50	R_{23} (50)
37·801	—	1	844·41	R_1 (51)
37·702	—	5	844·80	R_{23} (51)
33·774	—	2?	860·29	R_1 (52)
33·642	—	2?	860·81	R_{23} (52)
30·021	—	1	875·11	R_1 (53)
29·918	—	5	875·51	R_{23} (53)
25·879	—	1	891·49	R_1 (54)
25·769	—	4	891·92	R_{23} (54)
22·038	—	1	906·70	R_1 (55)
21·933	—	3*d*	907·12	R_{23} (55)
17·787	—	1	923·57	R_1 (56)
17·685	—	3	923·97	R_{23} (56)
13·857	—	1	939·18	R_1 (57)
13·757	—	4	939·58	R_{23} (57)
09·508	—	0	956·49	R_1 (58)
09·402	—	3	956·91	R_{23} (58)
05·486	—	0	972·53	R_1 (59)
05·387	—	4	972·92	R_{23} (59)
01·034	—	0	990·30	R_1 (60)
00·925	—	3	990·74	R_{23} (60)
4996·925	—	0	20006·74	R_1 (61)
96·829	—	4	007·13	R_{23} (61)
92·371	—	0	024·99	R_1 (62)
92·266	—	2	025·41	R_{23} (62)
88·182	—	0	041·81	R_1 (63)
88·094	—	3	042·16	R_{23} (63)
83·517	—	0*d*	060·57	R_1 (64)
83·450	—	2*d*	060·84	R_{23} (64)
—	—	—	—	R_1 (65)
79·172	—	2	078·57	R_{23} (65)
74·532	—	0	096·80	R_1 (66)
74·427	—	2	097·23	R_{23} (66)
70·166	—	0	114·46	R_1 (67)
70·079	—	2	114·81	R_{23} (67)
—	—	—	—	R_1 (68)
65·230	—	2	134·45	R_{23} (68)
—	—	—	—	R_1 (69)
60·811	—	2	152·39	R_{23} (69)
—	—	—	—	R_1 (70)
55·944	—	1	172·18	R_{23} (70)
—	—	—	—	R_1 (71)
51·382	—	1	20190·76	R_{23} (71)
—	—	—	—	R_1 (72)
46·320	—	1	211·43	R_{23} (72)

Table I (continued).

λ (I.A.).	Int. (Tube).	Int. (Arc).	ν (Vacuo).	Series.
—	—	—	—	R_1 (73)
4941·799	—	0	20229·92	R_{23} (73)
—	—	—	—	R_1 (74)
36·649	—	0	251·02	R_{23} (74)
—	—	—	—	R_2 (75)
32·009	—	0	270·07	R_{23} (75)

Notes.

* =Head of band.

In the two columns of intensities estimates are on the scale 0–10 as is usual. In the parts of great line density both columns have not as a rule been completed, but only that which is related to the measured wave-length. These remarks apply to all the bands, both of this and the other tables.

Table II.

λ (I.A.).	Int. (Tube).	Int. (Arc).	ν (Vacuo).	Series.
4737·084*	10	10	21104·15	P_1 (20), etc.
36·955	10*d*	10	104·72	P_2 (19), etc.
36·859	8	9	105·15	P_1 (21), etc.
36·796	5	?	105·43	P_2 (20), etc.
36·697	3*c*	3	105·87	P_2 (21)
36·636	10	10	106·14	P_3 (21), P_1 (22)
36·532	5	7	106·61	P_2 (22)
36·444	9*c*	4*vc*	107·00	P_3 (22), P_1 (23)
36·311	5*c*	—	107·59	P_2 (23)
36·228	6	7	107·96	P_3 (23)
36·141	6	4	108·35	P_1 (24)
36·038	6	—	108·81	P_2 (24)
35·952	7	9*vd*	109·19	P_3 (24)
35·839	5	4	109·69	P_1 (25)
35·714	5	8	110·26	P_2 (25)
35·629	8	—	110·63	P_3 (25)
35·447	7	5	111·45	P_1 (26)
35·356	7	—	111·85	P_2 (26)
35·275	7	9	112·21	P_3 (26)
35·034	6	4	113·29	P_1 (27)
34·942	6	—	113·70	P_2 (27)
34·863	7	8	114·05	P_3 (27)
34·555	6	3	115·42	P_1 (28)
34·491	6	—	115·71	P_2 (28)
34·422	7	9	116·02	P_3 (28)
34·021	5	3	117·80	P_1 (29)
33·953	8	9	118·11	P_{23} (29)
33·538	—	3?	119·96	P_1 (30)
33·418	10	10	120·49	P_{23} (30)
32·909	5*c*	3	122·76	P_1 (31)
32·810	8	8	123·21	P_{23} (31)

Table II (continued).

λ (I.A.).	Int. (Tube).	Int. (Arc).	ν (Vacuo).	Series.
4732·300	4	5	21125·48	P_1 (32)
32·181	4	9	126·02	P_{23} (32)
31·922	2	—	127·17	
31·898	—	2*c*	127·28	P_1 (33)
31·830	1	—	127·58	
31·814	—	4*c*	127·65	P_{23} (33)
31·391	0	—	129·50	
30·887	—	3	131·79	P_1 (34)
30·776	5*d*	8	132·29	P_{23} (34)
30·532	1*d*	—	133·38	
30·437	4	—	133·80	
30·353	3	—	134·18	
30·246	2	—	134·66	
30·089	2*vd*	—	135·36	R_2 (2), R_1 (3)
30·009	—	4*d*	135·71	P_1 (35)
29·904	2*d*	—	136·18	
29·862	—	5*vd*	136·37	P_{23} (35)
29·629	0	—	137·41	
29·408	0*c*	—	138·40	
29·351	1	—	138·65	R_2 (3)
29·261	—	4*c*	139·06	P_1 (36)
29·199	0	7*c*	139·33	P_{23} (36)
29·082	2	—	139·86	R_1 (4)
28·770	0	—	141·25	
28·584	0	—	142·08	
28·480	6	—	142·55	R_3 (3), R_2 (4)
28·328	0	4*c*	143·23	P_1 (37)
28·221	—	5*vd*	143·71	P_{23} (37)
28·110	5	—	144·20	R_1 (5)
27·889	0	—	145·19	
27·711	6	—	145·99	R_3 (4)
27·596	6	0	146·50	R_2 (5)
27·506	—	7	146·91	P_1 (38)
27·424	—	4	147·27	P_{23} (38)
27·271	0	—	147·96	
27·008	6	0	149·13	R_1 (6)
26·895	6	0	149·64	R_3 (5)
26·614	6	0	150·90	R_2 (6)
26·333	0	10	152·15	P_{123} (39)
26·003	10	1	153·63	R_3 (6), R_1 (7)
25·806	0	—	154·51	
25·611	7	0	155·38	R_2 (7)
25·586	—	5	155·50	P_1 (40)
25·482	0	8	155·96	P_{23} (40)
25·085	8	0	157·74	R_3 (7)
24·845	7	1	158·82	R_1 (8)
24·545	8	1	160·16	R_2 (8)
24·426	—	3	160·69	P_1 (41)
24·338	—	7	161·08	P_{23} (41)
24·094	8	1	162·18	R_3 (8)
24·013	1	—	162·54	
23·751	8	1	163·71	R_1 (9)
23·455	—	5*c*	165·04	P_1 (42)
23·449	8	*c*	165·07	R_2 (9)
23·380	—	4*c*	165·38	P_{23} (42)

Table II (continued).

λ (I.A.).	Int. (Tube).	Int. (Arc).	ν (Vacuo).	Series.
4723·056	9	1	21166·83	R_3 (9)
22·760	0	—	168·16	
22·550	9	1	169·10	R_1 (10)
22·300	9	*c*	170·22	R_2 (10)
22·215	—	4	170·60	P_1 (43)
22·106	—	8*vc*	171·09	P_{23} (43)
21·958	9	2	171·75	R_3 (10)
21·820	0	—	172·37	
21·381	9	2	174·34	R_1 (11)
21·148	—	6*c*	175·38	P_1 (44)
21·119	9	*c*	175·51	R_2 (11)
21·047	—	8*vc*	175·84	P_{23} (44)
20·822	9	3	176·85	R_3 (11)
20·100	8	3	180·09	R_1 (12)
19·886	8	*c*	181·05	R_2 (12)
19·831	—	3*vc*	181·29	P_1 (45)
19·732	—	7*vc*	181·74	P_{23} (45)
19·617	8	2	182·25	R_3 (12)
18·852	8	2	185·69	R_1 (13)
18·706	—	3	186·34	P_1 (46)
18·621	8	*c*	186·72	R_2 (13)
18·609	—	9	186·78	P_{23} (46)
18·390	8	3	187·76	R_3 (13)
17·490	8	3	191·80	R_1 (14)
17·303	8	*c*	192·64	R_2 (14)
17·290	—	6	192·70	P_1 (47)
17·181	—	7*c*	193·19	P_{23} (47)
17·086	8	3	193·62	R_3 (14)
16·871	0	—	194·59	
16·162	8	2	197·77	R_1 (15)
16·068	—	2	198·19	P_1 (48)
15·968	—	10	198·64	P_{23} (48)
15·953	8	*c*	198·71	R_2 (15)
15·769	8	4	199·54	R_3 (15)
15·294	1*c*	—	201·67	
15·231*	8	—	201·96	
15·123	5	—	202·44	
15·054	5	—	202·75	
14·949	7	—	203·22	
14·817	2*cd*	—	203·82	
14·724	8*cd*	—	204·24	R_1 (16)
14·544	10*d*	—	205·04	R_2 (16), P (49)?
14·357	10*d*	—	205·89	R_3 (16)
14·211	9	—	206·54	
14·032	6	—	207·35	
13·876	7	—	208·05	
13·716	6	—	208·77	
13·470	8*d*	—	209·87	
13·323	9	—	210·54	R_1 (17)
13·178	—	9	211·19	P_{23} (50)
13·166	2*c*	—	211·24	
13·129	6*c*	—	211·41	R_2 (17)
13·027	6	—	211·87	
12·940	7	—	212·26	R_3 (17)
12·774	0	—	213·01	

Table II (continued).

λ (I.A.).	Int. (Tube).	Int. (Arc).	ν (Vacuo).	Series.
4712·637	5	—	21213·63	
12·564	6	—	213·96	
12·483	6	—	214·32	
12·249	1	—	215·37	
12·086	5	—	216·11	
12·009	6*d*	—	216·45	
11·877	0	—	217·05	
11·785	—	2	217·46	P_1 (51)
11·783	5	—	217·47	R_1 (18)
11·647	—	6*c*	218·08	P_{23} (51)
11·636	5	—	218·13	R_2 (18)
11·485	10	—	218·81	R_3 (18)
11·143	—	—	220·35	
11·025	—	—	220·88	
10·948	2	—	221·23	
10·897	2*c*	—	221·46	
10·809	2	—	221·86	
10·448	—	3	223·48	P_1 (52)
10·327	—	5*vc*	224·03	P_{23} (52)
10·288	8	—	224·20	R_1 (19)
10·195	—	—	224·63	
10·113	7	—	224·99	R_2 (19)
10·048	0	—	225·28	
09·994	7	—	225·53	R_3 (19)
09·874	—	3	226·07	
09·740	—	10	226·67	
09·727	3	—	226·74	
09·377	1	—	228·31	
09·203	2	—	229·10	
09·087	—	3	229·62	P_1 (53)
08·970	—	6*d*	230·15	P_{23} (53)
08·892	2*d*	—	230·50	
08·673	6	—	231·49	R_1 (20)
08·534	7*c*	—	232·11	R_2 (20)
08·398	6*c*	—	232·73	R_3 (20)
08·311	—	9	233·12	
08·270	3*c*	—	233·30	R_2' (2) ?
08·173	0	—	233·74	
08·016	0	—	234·45	
07·917	0	—	234·89	
07·817	1	—	235·34	
07·568	—	3	236·47	P_1 (54)
07·470	2*vd*	—	236·91	R_2' (3) ?
07·449	—	7	237·00	P_{23} (54)
07·289	2*c*	—	237·73	R_1' (4) ?
07·094	4	—	238·61	R_1 (21)
07·070	—	5*c*	238·72	
07·010	0	—	238·99	
06·928	5	—	239·36	R_2 (21)
06·833	—	8	239·78	
06·830	5	—	239·80	R_3 (21)
06·713	0	8	240·33	
06·633	4	—	240·69	R_2' (4) ?
06·524	0	—	241·18	

Table II (continued).

λ (I.A.).	Int. (Tube).	Int. (Arc).	ν (Vacuo).	Series.
4706·297	3	—	21242·21	R_1' (5) ?
06·099	0	—	243·10	
05·880	4	5	244·09	R_3' (4) ?
05·780	7	5	244·54	R_2' (5) ?
05·404	4*d*	5	246·24	R_1 (22)
05·384	—	5*c*	246·33	
05·266	7	9	246·92	R_2 (22), R_3' (5)?
05·159	4	—	247·34	R_3 (22)
05·086	6	—	247·67	R_1' (6) ?
05·064	—	2	247·77	
04·947	0	9	248·30	
04·829	6	—	248·83	R_2' (6)
04·564	0	—	250·02	
04·247	9*d*	—	251·46	R_3' (6), R_1' (7) ?
04·023	—	3	252·47	
03·870	7	6*c*	253·16	R_2' (7)
03·748	6	8	253·71	R_1 (23)
03·591	5	4	254·42	R_2 (23)
03·503	5	4	254·82	R_3 (23)
03·330	7	—	255·60	R_3' (7) ?
03·123	—	4	256·54	
03·096	7	—	256·65	R_1' (8) ?
03·018	—	7	257·01	
02·850	7	—	257·77	R_2' (8) ?
02·366	8	—	259·95	R_3' (8) ?
02·044	6	—	261·41	R_1' (9) ?
01·963	5	—	261·78	R_1 (24)
01·863	—	10*c*	262·24	
01·825	8	—	262·40	R_2 (24), R_2' (9) ?
01·734	5	—	262·82	R_3 (24)
01·374	8	—	264·44	R_3' (9)
01·034	—	2	265·98	
00·927	—	7*c*	266·47	
00·873	9	—	266·71	
00·303	7	—	269·29	
00·229	2	—	269·62	R_1 (25)
00·078	2	—	270·30	R_2 (25)
00·009	2	—	270·62	R_3 (25)
4699·844	—	2	271·37	
99·748	7	—	271·80	
99·741	—	7*c*	271·84	
99·284	6	—	273·90	R_2' (11) ?
99·224	7	—	274·17	
98·783	—	2	276·17	
98·677	—	5	276·65	
98·514	7	—	277·38	R_1' (12) ?
98·354	4	—	278·11	R_1 (26)
98·212	8	—	278·75	R_2 (26), R_2' (12) ?
98·147	0	—	279·04	R_3 (26)
98·063	6	—	279·43	R_3' (12) ?
97·604*	9	—	281·51	
97·512	3*c*	—	281·93	
97·456	5	—	282·18	
97·394	7	—	282·46	
97·300	9	—	282·89	

Table II (continued).

λ (I.A.).	Int. (Tube).	Int. (Arc).	ν (Vacuo).	Series.
4697·223	1*c*	—	21283·23	
97·149	4*c*	—	283·57	
97·051	3*c*	—	284·01	R_2' (13) ?
96·980	3*c*	—	284·33	
96·889	9	—	284·75	
96·771	3	—	285·28	
96·653	9	—	285·82	
96·505	7*d*	—	286·49	R_1 (27)
96·402	6	—	286·95	R_2 (27)
96·340	6	—	287·23	R_3 (27)
96·220	6*d*	—	287·78	
96·164	0	—	288·03	
96·084	2	—	288·39	
96·013	6	—	288·72	
95·858	6*d*	—	289·42	
95·751	10	—	289·90	R_2' (14) ?
95·614	6	—	290·53	
95·499	6*c*	—	291·05	
95·351	6	—	291·72	
95·207	6	—	292·37	
95·062	6	—	293·03	
94·953	6	—	293·53	
94·699	7	—	294·68	
94·610	6	—	295·08	R_1 (28), R_2' (15) ?
94·479	8	—	295·68	R_2 (28)
94·175	5	—	297·06	R_3 (28)
94·095	5	—	297·42	
94·005	7	—	297·83	
93·790	—	4	298·80	
93·700	—	7*d*	299·21	
93·564	6	—	299·83	
93·470	5*d*	—	300·26	
93·316	5	—	300·96	R_1' (16) ?
93·109	5	—	301·90	R_2' (16) ?
92·942	5*d*	—	302·65	R_3' (16) ?
92·852	4	6	303·06	
92·675	1	6*d*	303·86	R_1 (29)
92·568	0	3*d*	304·35	R_2 (29)
92·476	0	—	304·77	R_3 (29)
92·369	2	—	305·25	
92·226	1	—	305·90	
92·132	1	—	306·33	
91·961	5	5	307·11	R_1' (17) ?
91·853	0	—	307·60	
91·759	5	5	308·02	R_2' (17) ?
91·678	0	—	308·39	
91·561	5	1	308·92	R_3' (17) ?
91·306	0*d*	—	310·08	
90·982	1*vd*	6*c*	311·56	
90·787	0*d*	—	312·44	R_2 (30)
90·554	6	6	313·50	R_3 (30)
90·493	7	*c*	313·78	R_1' (18) ?
90·407	2	3*c*	314·17	
90·295	7	2	314·68	R_2' (18) ?
90·117	7	2	315·49	R_3' (18) ?

Table II (continued).

λ (I.A.).	Int. (Tube).	Int. (Arc).	ν (Vacuo).	Series.
4689·976	0	—	21316·13	
89·871	1	—	316·60	
89·790	0	—	316·97	
89·626	2	—	317·72	
89·453	2*d*	5	318·50	
89·331	—	6	319·06	
89·266	0	—	319·35	
89·238	—	7	319·48	
89·140	0	—	319·93	
89·048	7	2	320·34	
88·890	0	2	321·06	
88·798	2	4	321·48	
88·700	9*d*	8	321·93	R_2' (19) ?
88·494	7	8	322·86	
88·349	2	—	323·52	
88·288	1	—	323·80	
88·193	—	2	324·23	
88·105	—	6	324·63	
88·078	1*d*	—	324·75	
87·959	7*c*	—	325·29	
87·892	4*c*	—	325·60	
87·647	0	—	326·71	
87·490	6*c*	2	327·43	
87·443	6*c*	—	327·64	
87·332	3	—	328·15	
87·198	7*d*	8	328·76	
87·012	6*d*	—	329·60	
86·877	—	1	330·22	
86·737	2	—	330·86	
86·730	—	4*c*	330·89	
86·527	00	—	331·81	
86·483	5	5*vc*	332·01	
86·379	5	—	332·49	
86·281	1	—	332·93	
86·070	5	—	333·89	
86·003	5	6	334·20	
85·915	—	1	334·60	
85·812	—	2	335·07	
85·807	4	—	335·09	
85·700	4	3	335·58	
85·514	7	—	336·42	
85·424	—	1*c*	336·83	
85·395	5	—	336·95	
85·307	—	3*c*	337·37	
85·261	0	—	337·58	
85·077	5	—	338·41	
84·974	5	—	338·88	
84·880	5	—	339·31	
84·777*	4*dc*	—	339·78	
84·709	9*c*	—	340·09	
84·610	9*c*	—	340·58	
84·553	9*c*	—	340·80	
84·432	2*c*	—	341·35	
84·362	9*c*	—	341·67	
84·327	5*c*	—	341·83	

Table II (continued).

λ (I.A.).	Int. (Tube).	Int. (Arc).	ν (Vacuo).	Series.
4684·219	7*d*	—	21342·32	
84·066	6*c*	—	343·02	
83·999	4*c*	—	343·32	
83·895	2	—	343·80	
83·710	6*dc*	—	344·64	
83·629	5	—	345·01	
83·545	3	—	345·39	
83·432	7	—	345·91	
83·237	6*d*	—	346·79	
82·981	8	—	347·97	
82·855	3	—	348·54	
82·808	4	—	348·75	
82·713	4	—	349·19	
82·609	7	7	349·66	
82·518	5	—	350·08	
82·428	4	—	350·49	
82·168	8	—	351·67	
82·025	1	—	352·32	
81·949	0?	—	352·67	
81·872	8	—	353·02	
81·735	0 ?	—	353·65	
81·645	1	—	354·06	
81·551	8	—	354·49	
81·439	3	—	355·00	
81·156	2	—	356·29	
81·054	5	—	356·75	
80·959	6	—	357·19	
80·906	6	—	357·43	
80·770	0*d*	—	358·05	
80·728	6	—	358·24	
80·426	7*d*	—	359·62	
80·163	3*d*	—	360·82	
80·056	1	—	361·31	
79·854	4	—	362·05	
79·814	6	—	362·41	
79·686	1	—	363·00	
79·557	5	—	363·81	
79·480	0	—	363·94	
79·389	2	—	364·35	
79·301	7*c*	—	364·75	
79·248	3*c*	—	365·00	
79·154	4*d*	—	365·43	
79·035	0	—	365·97	
78·918	1*d*	—	366·50	
78·786	3	—	367·11	
78·691	1	—	367·54	
78·595*	4*c*	—	367·98	
78·548	6*c*	—	368·19	
78·459	3*vd*	—	368·60	
78·346	9	—	369·11	
78·212	5	—	369·73	
78·097	7*d*	—	370·25	
77·878	5*vc*	—	371·25	
77·752	3	—	371·83	
77·681	3	—	372·25	

Table II (continued).

λ (I.A.).	Int. (Tube).	Int. (Arc).	ν (Vacuo).	Series.
4677·604	1*c*	—	21372·50	
77·518	4*c*	—	372·90	
77·453	6*c*	—	373·19	
77·324	7*vd*	—	373·78	
77·167	1	—	374·50	
77·055	5*d*	—	375·01	
76·887	7	—	375·78	
76·818	0*c*	—	376·09	
76·736	4	—	376·47	
76·662	4	—	376·81	
76·551	2	—	377·31	
76·394	7*d*	—	378·03	
76·203	5*c*	—	378·91	
76·152	4*c*	—	379·14	
75·996	8*d*	—	379·86	
75·906	1	—	380·27	
75·798	6	—	380·76	
75·659	4*c*	—	381·40	
75·578	6*vc*	—	381·77	
75·421	3*d*	—	382·48	
75·333	0	—	382·89	
75·184	5*c*	—	383·57	
75·120	0*c* ?	—	383·86	
74·932	2*vd*	—	384·72	
74·687	5*d*	—	385·84	
74·464	7*d*	—	386·86	
74·303	5	—	387·60	
74·235	4	—	387·91	
74·085	3*c*	—	388·59	
73·911	2*vd*	—	389·39	
73·735	3	—	390·20	
73·635	0	—	390·65	
73·566	1	—	390·97	
73·450	6	—	391·50	
73·334	3*c*	—	392·03	
73·273	4*c*	—	392·31	
73·166	3*d*	—	392·80	
73·096	6	—	393·12	
72·924	5	—	393·91	
72·769	3	—	394·62	
72·588	8	—	395·45	
72·370	0*d*	—	396·44	
72·258	1*c*	—	396·96	
72·191	0*c*	—	397·26	
72·049	1	—	397·91	
71·901	6	—	398·60	
71·809	5	—	399·02	
71·705	6	—	399·49	
71·555	7*d*	—	400·18	
71·364	1	—	401·05	
71·182	5	—	401·89	
71·044	1*d*	—	402·52	
70·918	0*d*	—	403·10	
70·789	5	—	403·69	
70·670	3	—	404·23	

Table II (continued).

λ (I.A.).	Int. (Tube).	Int. (Arc).	ν (Vacuo).	Series.
4670·428	6*d*	—	21405·34	
70·280	6*d*	—	406·02	
70·202	0*c*	—	406·38	
70·109	7	—	406·80	
69·998	1	—	407·31	
69·824	3*c*	—	408·11	
69·787	0*c*	—	408·28	
69·508	1	—	409·56	
69·417	7	—	409·98	
69·130	5*c*	—	411·29	
68·981	5*c*	—	411·97	
68·807	7	—	412·77	
68·688	6	—	413·32	
68·572	1*c*	—	413·85	
68·518	3*c*	—	414·10	
68·208	7*vd*	—	415·52	
67·923	7*d*	—	416·83	
67·835	1	—	417·23	
67·558	2*d*	—	418·50	
67·445	8	—	419·02	
67·325	3*c*	—	419·57	
67·281	4*c*	—	419·78	
67·161	7	—	420·33	
67·077	7	—	420·71	
66·765	5	—	422·14	
66·652	2	—	422·66	
66·521	2*c*	—	423·26	
66·368	3	—	423·97	
66·187	3	—	424·80	
66·095	2	—	425·22	
65·914	8	—	426·05	
65·810	0	—	426·53	
65·740	0	—	426·85	
65·659	9	—	427·22	
65·579	0	—	427·59	
65·344	4	—	428·67	
65·276	1	—	428·98	
65·063	5	—	429·96	
64·806	6	—	431·14	
64·717	6	—	431·55	
64·543	5	—	432·35	
64·300	8*vd*	—	433·46	
64·138	2*d*	—	434·21	
64·035	2*d*	—	434·68	
63·943	2	—	435·11	
63·857	3	—	435·50	
63·653	4	—	436·44	
63·475	5*d*	—	437·26	
63·350	4	—	437·83	
63·255	4*d*	—	438·27	
63·107	2	—	438·95	
63·004	4	—	439·42	
62·931	4	—	439·76	
62·687	4*d*	—	440·88	
62·554	5	—	441·49	

Table II (continued).

λ (I.A.).	Int. (Tube).	Int. (Arc).	ν (Vacuo).	Series.
4662·458	2	—	21441·93	
62·331	5*d*	—	442·52	
62·210	3	—	443·07	
62·083	4	—	443·66	
61·982	3	—	444·12	
61·887	6*c*	—	444·56	
61·584	5	—	445·95	
61·292	4*vd*	—	447·29	
60·941	6*vd*	—	448·91	
60·776	2*c*	—	449·67	
60·740	3*c*	—	449·84	
60·634	2	—	450·33	
60·510	4*cd*	—	450·90	
60·253	6	—	452·08	
60·115	0	—	452·71	
59·981	4*c*	—	453·33	
59·771	4	—	454·30	
59·693	4	—	454·66	
59·483	4	—	455·62	
59·401	4	—	456·00	
59·324	4*cd*	—	456·35	
59·185	5*vd*	—	456·99	
58·955	2	—	458·05	
58·895	4	—	458·33	
58·690	3	—	459·27	
58·299	5*d*	—	461·07	
58·198	3	—	461·54	
58·046	7*c*	—	462·24	
57·824	7*c*	—	463·26	
57·589	1	—	464·34	
57·477	1	—	464·86	
57·376	1	—	465·33	
57·115	6	—	466·53	
56·901	6*cd*	—	467·52	
56·749	2	—	468·22	
56·665	1	—	468·61	
56·607	4	—	468·87	
56·099	1	—	471·22	
55·960	4	—	471·86	
55·827	2	—	472·47	
55·729	4	—	472·92	
55·660	0	—	473·24	
55·535	3	—	473·82	
55·396	2	—	474·46	
55·278	2	—	475·00	
55·080	2	—	475·92	
54·721	2*d*	—	477·57	
54·529	3	—	478·46	
54·438	1	—	478·88	
54·320	5	—	479·42	
54·159	1	—	480·16	
54·032	8	—	480·75	
53·933	0	—	481·21	
53·860	0	—	481·54	
53·756	3	—	482·02	

Table II (continued).

λ (I.A.).	Int. (Tube).	Int. (Arc).	ν (Vacuo).	Series.
4653·530	3	—	21483·07	
53·301	3	—	484·12	
53·136	3	—	484·88	
52·513	1	—	487·77	
52·451	1	—	488·05	
52·308	0	—	488·71	
52·235	4c	—	489·05	
52·166	4c	—	489·37	
52·040	5	—	489·95	
51·869	3	—	490·74	
51·403	0	—	492·89	
51·017	1c	—	494·68	
50·968	1c	—	494·90	
50·791	3d	—	495·72	
50·608	1	—	496·57	
50·496	0	—	497·08	
50·383	0	—	497·60	
50·254	0d	—	498·20	
50·113	1d	—	498·85	
49·943	1	—	499·64	
49·824	1	—	500·19	
49·608	1c	—	501·19	
49·554	1c	—	501·44	
49·439	1c	—	501·97	
49·383	1c	—	502·23	
49·292	1	—	502·65	
49·180	2d	—	503·17	
48·563	2	—	506·02	
48·303	4	—	507·23	
48·090	2c	—	508·21	
47·984	2c	—	508·70	
47·888	0	—	509·15	
47·691	1d	—	510·06	
47·530	0	—	510·80	
47·389	0	—	511·46	
47·239	1	—	512·15	
46·876	1d	—	513·83	
46·718	2	—	514·56	
46·588	4	—	515·16	
46·166	3	—	517·12	
45·996	1c	—	517·90	
45·885	1c	—	518·42	
45·746	0	—	519·06	
45·518	1d	—	520·12	
45·330	1	—	520·99	
45·223	1	—	521·48	
45·107	0	—	522·02	
44·892	0	—	523·02	
44·777	0	—	523·55	
44·588	0d	—	524·43	
44·417	2d	—	525·22	
44·068	1	—	526·84	
43·909	1	—	527·58	
43·810	1	—	528·03	
42·844	0vd	—	532·51	

Table II (continued).

λ (I.A.).	Int. (Tube).	Int. (Arc).	ν (Vacuo).	Series.
4642·668	1*c*	—	21533·33	
42·606	1*c*	—	533·62	
42·457	1	—	534·31	
42·363	1	—	534·74	
42·268	1	—	535·18	
42·160	1	—	535·68	
41·246	0	—	539·92	
41·014	1*vd*	—	541·00	
40·397	0	—	543·87	
39·635	0	—	547·41	
39·476	0	—	548·14	
39·401	0	—	548·49	

* = Head of a band.

TABLE III.

λ (I.A.).	Int. (Tube).	ν (Vacuo).	Series.
5635·525*	10	17739·67	P_1 (13), P_1 (14)
35·361	10*d*	740·17	P_1 (15)
35·236	10	740·57	P_1 (16), P_2 (15)
35·124	5*vd*	740·93	P_3 (15)
34·885	6*vd*	741·68	P_3 (16), P_1 (17)
34·626	5*d*	742·49	P_{23} (17)
34·515	7	742·84	P_1 (18)
34·346	5*c*	743·38	P_2 (18)
34·253	6*d*	743·67	P_3 (18)
34·146	3*c*	744·01	
34·000	3	744·47	P_1 (19)
33·853	6	744·93	P_2 (19)
33·763	7	745·21	P_3 (19)
33·667	3	745·51	
33·459	5	746·17	P_1 (20)
33·209	8*vd*	746·96	P_{23} (20)
32·776	5	748·32	P_1 (21)
32·634	3	748·77	P_2 (21)
32·503	7*d*	749·18	P_3 (21)
32·077	4*d*	750·53	P_1 (22)
31·849	5*d*	751·24	P_{23} (22)
31·193	3	753·31	P_1 (23)
31·030	5*d*	753·83	P_{23} (23)
30·309	4	756·10	P_1 (24)
30·124	5*d*	756·68	P_{23} (24)
29·456	0	758·79	
29·277	4	759·35	P_1 (25)
29·092	4*d*	759·94	P_{23} (25)
28·421	3	762·06	
28·219	7	762·69	P_1 (26)
28·028	7	763·30	P_{23} (26)

Table III (continued).

λ (I.A.).	Int. (Tube).	ν (Vacuo).	Series.
5627·697	0	17764·34	R_1 (3)
27·294	0	765·61	
26·989	3	766·57	P_1 (27)
26·822	5*d*	767·10	P_{23} (27), R_2 (3)
26·384	1	768·48	R_1 (4)
25·766	3	770·44	R_3 (3), P_1 (28)
25·580	5*d*	771·03	R_2 (4), P_{23} (28)
24·914	0*vd*	773·13	R_1 (5)
24·475	1	774·52	R_3 (4)
24·386	1	774·80	P_1 (29)
24·203	5*d*	775·38	P_{23} (29), R_2 (5)
23·254	6*d*	778·38	R_3 (5), R_1 (6)
22·972	1	779·27	P_1 (30)
22·804	2	779·80	P_{23} (30)
22·714	2	780·08	R_2 (6)
21·867	3	782·76	R_3 (6)
21·687	2	783·33	R_1 (7)
21·403	0	784·23	P_1 (31)
21·181	4*vd*	784·93	P_{23} (31), R_2 (7)
20·422	4	787·33	R_3 (7)
19·904	4	788·97	R_1 (8)
19·829	1	789·21	P_1 (32)
19·667	3	789·72	P_{23} (32)
19·493	3	790·27	R_2 (8)
19·282	2	790·94	
18·859	5	792·28	R_3 (8)
18·196	4	794·38	R_1 (9)
18·084	0	794·73	P_1 (33)
17·922	0*d*	795·25	P_{23} (33)
17·763	4	795·75	R_2 (9)
17·208	5	797·51	R_3 (9)
16·820	0	798·74	
16·289	5*d*	800·42	R_1 (10), P_1 (34)
16·190	1	800·74	P_{23} (34)
15·938	5	801·53	R_2 (10)
15·463	5	803·04	R_3 (10)
14·412	5	806·37	R_1 (11), P_1 (35)
14·225	4	806·97	P_{23} (35)
14·054	5	807·51	R_2 (11)
13·625	6	808·87	R_3 (11)
12·359	6	812·88	R_1 (12)
12·051	6	813·86	R_2 (12)
11·678	6	815·05	R_3 (12)
10·307	6*c*	819·40	R_1 (13), P_1 (37)
10·117	1	820·00	P_{23} (37)
09·983	6	820·43	R_2 (13)
09·668	6	821·43	R_3 (13)
08·109	6	826·38	R_1 (14)
07·843	6	827·23	R_2 (14)
07·538	6	828·20	R_3 (14)
07·058	0	829·72	
05·898	6	833·42	R_1 (15)
05·608	6	834·34	R_2 (15)
05·353	6	835·15	R_3 (15)
04·911	3	836·56	

Table III (continued).

λ (I.A.).	Int. (Tube).	ν (Vacuo).	Series.
5603·534	5	17840·95	R_1 (16)
03·292	5	841·72	R_2 (16)
03·055	5	842·47	R_3 (16)
02·194	0	845·21	
01·177	6	848·45	R_1 (17)
00·901	6	849·33	R_2 (17)
00·707	7*d*	849·95	R_3 (17)
5598·818	0	855·97	
98·639	5	856·54	R_1 (18)
98·422	5	857·23	R_2 (18)
98·211	5	857·91	R_3 (18)
96·112	5	864·60	R_1 (19)
95·873	5	865·37	R_2 (19)
95·698	5	865·93	R_3 (19)
95·418	3	866·82	
93·605	0	872·61	
93·412	5	873·23	R_1 (20)
93·212	5	873·86	R_2 (20)
93·043	5	874·40	R_3 (20)
91·373	0	879·74	
91·173	1	880·38	
90·729	4	881·80	R_1 (21)
90·511	4	882·50	R_2 (21)
90·363	4	882·97	R_3 (21)
88·782	0	888·03	
88·111	0	890·18	
87·875	4	890·93	R_1 (22)
87·685	4	891·54	R_2 (22)
87·529	4	892·04	R_3 (22)
85·724	1	897·83	P_2' (15) ?
85·491*	10	898·57	P_1' (16) ?
85·248	7*c*	899·35	P_2' (16) ?
85·199	9*cd*	899·51	P_1' (17) ?, P_3' (16) ?
85·019	6*c*	900·08	P_2' (17), R_1 (23)
84·887	8	900·51	P_3' (17), R_2 (23)
84·734	9	901·00	R_3 (23)
84·580	7	901·49	P_1' (18)
84·414	5	902·03	P_2' (18)
84·299	5	902·39	P_3' (18)
84·106	5*vd*	903·01	
83·952	2*c*	903·51	P_1' (19)
83·838	3*c*	903·87	P_{23}' (19)
83·577	5*d*	904·71	P_1' (20)
83·374	5*d*	905·36	P_{23}' (20)
83·071	1*d*	906·33	
82·991	6*c*	906·59	
82·820	3	907·14	P_1' (21)
82·730	5	907·42	P_{23}' (21)
82·402	7	908·48	
82·299	5	908·81	
82·112	3	909·41	P_1' (22)
82·042	5	909·63	P_{23}' (22), R_1 (24)
81·841	2	910·28	R_2 (24)
81·698	6	910·73	R_3 (24)
81·509	3	911·34	

Table III (continued).

λ (I.A.).	Int. (Tube).	ν (Vacuo).	Series.
5581·357	3	17911·83	P_1' (23)
81·269	3	912·11	P_{23}' (23)
81·015	0	912·93	
80·495	4*c*	914·60	P_1' (24)
80·439	4*c*	914·78	P_{23}' (24)
79·694	2	917·17	
79·555	2	917·61	P_1' (25)
79·481	2	917·85	P_{23}' (25)
79·019	3	919·34	R_1 (25)
78·805	2	920·02	R_2 (25)
78·703	4*d*	920·35	R_3 (25), P_1' (26)
78·472	3*d*	921·09	P_{23}' (26)
78·043	0	922·47	
77·734	0	923·46	
77·549	1	924·06	P_1' (27)
77·397	2*c*	924·55	P_{23}' (27)
77·339	2*c*	924·74	
76·384	0	927·80	
76·191	2*d*	928·42	P_{23}' (28)
75·842	4	929·55	R_1 (26)
75·684	3	930·05	R_2 (26)
75·540	2	930·52	R_3 (26)
75·102	3	931·93	R_1' (5)
74·924	2*vd*	932·50	
74·623	0	933·47	
74·406	1	934·16	R_2' (5)
73·752	0*d*	936·27	
73·548	3*d*	936·92	R_3' (5), R_1' (6)
73·428	1	937·31	
72·949	2*d*	938·85	R_2' (6)
72·679	1	939·72	R_1 (27)
72·506	1*c*	940·28	R_2 (27)
72·401	1*c*	940·62	R_3 (27)
72·127	4	941·50	R_3' (6)
71·991	2	941·94	R_1' (7)
71·458	4	943·65	R_2' (7)
70·730	2*c*	946·00	R_3' (7)
70·634	0	946·31	
70·287	3	947·42	R_1' (8)
69·852	3	948·83	R_2' (8)
69·202	4	950·92	R_3' (8)
69·064	1	951·37	
68·621	3	952·80	R_1' (9)
68·193	3	954·18	R_2' (9)
67·621	3	956·02	R_3' (9)
67·313	1	957·01	
66·783	3	958·72	R_1' (10)
66·427	3	959·87	R_2' (10)
66·061	1	961·05	R_1 (28)
65·940	3*c*	961·44	R_2 (28), R_3' (10)
65·772	3*c*	961·99	R_3 (28)
64·972	4	964·57	R_1' (11)
64·601	4	965·77	R_2' (11)
64·171	4	967·15	R_3' (11)
63·713	0	968·63	

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Table III (continued).

λ (I.A.).	Int. (Tube).	ν (Vacuo).	Series.
5562·993	3	17970·96	R_1' (12)
62·684	3	971·95	R_2' (12)
62·297	4*d*	973·20	R_3' (12)
61·286	0	976·47	
61·034	3	977·29	R_1' (13)
60·708	3	978·34	R_2' (13)
60·590	0	978·72	
60·368	4	979·44	R_3' (13)
59·056	2	983·68	
58·902	3*c*	984·18	R_1' (14)
58·626	3	985·07	R_2' (14)
58·315	3	986·08	R_3' (14)
57·480	2	988·79	
56·776	4	991·06	R_1' (15)
56·482	4	992·02	R_2' (15)
56·229	4	992·83	R_3' (15)
55·933	1	993·79	
55·406	1*d*	995·50	
55·192	0*d*	996·19	
54·506	3*c*	998·41	R_1' (16)
54·244	3	999·26	R_2' (16)
53·997	3	18000·07	R_3' (16)
53·036	0*d*	003·18	
52·216	3	005·84	R_1' (17)
51·954	3	006·69	R_2' (17)
51·738	3	007·39	R_3' (17)
51·615	1*c*	007·79	
50·917	1	010·05	
50·351	1	011·89	
49·781	3	013·74	R_1' (18)
49·562	3	014·45	R_2' (18)
49·347	3	015·15	R_3' (18)
49·084	0	016·00	
47·917	2	019·79	
47·357	3	021·61	R_1' (19)
47·099	3	022·45	R_2' (19)
46·915	3	023·04	R_3' (19)
45·655	0	027·14	
44·975	0	029·35	
44·753	2	030·07	R_1' (20)
44·565	2	030·68	R_2' (20)
44·369	2	031·32	R_3' (20)
43·618	0	033·76	
42·644	0	036·94	
42·176	2	038·46	R_1' (21)
41·942	2*c*	039·22	R_2' (21)
41·780	2	039·75	R_3' (21)
40·681*	4*vd*	043·32	P_1'' (16), P_2'' (14)
40·439	9*d*	044·11	P_2'' (16), P_2'' (15)
40·193	8	044·91	P_1'' (17)
39·940	5*d*	045·74	P_{23}'' (17), P_1'' (18)
39·709	5*d*	046·49	P_{23}'' (18)
39·562	3*d*	046·97	P_1'' (19) ?
39·427	3*c*	047·41	R_1' (22)
39·337	3	047·70	P_{23}'' (19)

Table III (continued).

λ (I.A.).	Int. (Tube).	ν (Vacuo).	Series.
5539·211	3	18048·11	R_2' (22)
39·066	3	048·59	R_3' (22)
38·747	2	049·63	P_{23}'' (20)
38·611	0	050·07	
38·478	0	050·50	P_1'' (21)
38·234	3*vd*	051·30	P_{23}'' (21)
37·876	1	052·46	P_1'' (22) ?
37·602	3*d*	053·36	P_{23}'' (22) ?
37·380	0	054·08	
37·130	0	054·90	P_1'' (23) ?
36·934	1	055·53	P_{23}'' (23) ?
36·826	1	055·89	
36·693	1	056·32	R_1' (23)
36·464	1	057·07	R_2' (23)
36·339	3	057·47	R_3' (23)
36·103	3	058·24	P_{23}'' (24) ?
34·761	0	062·62	
34·551	0	063·31	
34·312	0*dc*	064·09	
33·770	2*vd*	065·86	R_1' (24)
33·577	5*c*	066·49	R_{23}' (24)
32·370	0	070·43	
32·164	1*vd*	071·10	
30·876	1	075·31	R_1' (25)
30·682	1	075·95	R_2' (25)
30·575	1	076·30	R_3' (25)
29·955	0	078·32	
29·730	1*d*	079·06	
28·984	0	081·50	
28·841	0	081·96	
28·538	0	082·95	
28·404	0	083·39	
27·821	1*d*	085·30	R_1' (26)
27·547	2*vd*	086·20	R_{23}' (26)
27·175	0	087·42	
26·975	1*d*	088·07	
26·216	0*d*	090·55	
25·783	0	091·97	
25·601	1	092·57	
25·445	1	093·08	
24·763	3	095·31	
24·593	2	095·87	
24·503	2	096·16	
24·212	0	097·11	
23·879	2	098·21	
23·521	1	099·38	
23·241	1	100·30	
22·405	2*d*	103·04	
22·162	10	103·83	
21·603	2	105·67	
21·406	1	106·31	
21·304	1	106·65	
20·712	0	108·59	
20·050	0	110·76	
19·932	1*d*	111·15	
18·786	2	114·91	R_1'' (12)

Table III (continued).

λ (I.A.).	Int. (Tube).	ν (Vacuo).	Series.
5518·366	2	18116·29	R_2'' (12)
18·134	2	117·05	R_3'' (12)
16·864	1*c*	121·22	R_1'' (13)
16·507	1	122·39	R_2'' (13)
16·339	1	122·94	R_3'' (13)
14·884	2*d*	127·73	R_1'' (14) ?
14·487	2	129·03	R_{23}'' (14)
12·794	1	134·60	R_1'' (15) ?
12·477	1	135·64	R_{23}'' (15)
11·805	0	137·85	
11·688	0	138·24	
11·451	0*d*	139·02	
10·601	1	141·81	R_1'' (16)
10·301	1	142·80	R_2'' (16)
09·931	1	144·02	R_3'' (16)
08·602	1	148·40	
08·420	2	149·00	R_1'' (17)
08·137	1	149·93	R_2'' (17)
07·834	1	150·93	R_3'' (17)
06·042	1	156·83	R_1'' (18)
05·795	1	157·65	R_2'' (18)
05·542	1	158·48	R_3'' (18)
04·671	0	161·36	
04·510	0*vd*	161·89	
03·731	1	164·46	R_1'' (19)
03·465	1	165·34	R_2'' (19)
03·244	1	166·07	R_3'' (19)
01·911*	3	170·47	
01·718	3	171·11	
01·581	9	171·56	
01·415	6	172·11	
01·230	1	172·72	R_1'' (20)
01·133	1	173·04	
00·979	7	173·55	R_2'' (20)
00·804	4	174·13	R_3'' (20)
00·597	4	174·81	
00·374	1	175·55	
00·228	0	176·03	
00·071	0	176·55	
5499·924	0	177·03	
99·496	0	178·45	
99·312	1*c*	179·05	
99·197	1*c*	179·44	
98·723	1	181·00	R_1'' (21)
98·502	0	181·73	R_2'' (21)
98·331	0	182·30	R_3'' (21)
98·172	0	182·83	
97·904	1*d*	183·71	
97·354	0	185·53	
97·174	1*d*	186·13	
96·491	0*d*	188·38	
96·291	0	189·05	
96·104	0	189·67	R_1'' (22)
95·896	0	190·35	R_2'' (22)
95·687	0*vd*	191·05	R_3'' (22)

Table III (continued).

λ (I.A.).	Int. (Tube).	ν (Vacuo).	Series.
5494·746	0	18194·16	
94·591	0	194·67	
94·342	0	195·50	
93·491	0	198·31	R_1'' (23)
93·260	0	199·08	R_2'' (23)
93·120	0	199·54	R_3'' (23)
90·702	1*d*	207·56	R_1'' (24)
90·465	0	208·35	R_2'' (24)
90·310	1	208·86	R_3'' (24)
90·031	1	209·79	
89·656	1*vd*	211·03	R_2''' (6)
89·250	0	212·38	
88·829	0	213·77	R_1''' (7)
88·307	1	215·51	R_2''' (7)
87·933	1	216·75	R_1'' (25)
87·707	0	217·50	R_{23}'' (25)
87·543	0	218·04	R_3''' (7)
87·269	0	218·95	R_1''' (8)
86·784	0	220·56	R_2''' (8)
86·136	0	222·72	R_3''' (8)
85·734	1	224·05	R_1''' (9)
85·529	0	224·73	
85·246	0	225·67	R_2''' (9)
85·010	0	226·46	R_1'' (26)
84·658	1*d*	227·62	R_{23}'' (26), R_3''' (9)
84·019	0	229·75	R_1''' (10)
83·634	1	231·03	R_2''' (10)
83·100	1	232·81	R_3''' (10)
82·336	1	235·35	R_1''' (11)
81·903	1	236·79	R_2''' (11)
81·750	1	238·30	R_{23}'' (27) ?
81·477	1	238·20	R_3''' (11)
80·491	1	241·48	R_1''' (12)
80·168	1	242·56	R_2''' (12)
79·739	1	243·99	R_3''' (12)
78·942	1*d*	246·64	
78·686	1*d*	247·49	R_1''' (13)
78·329	1*d*	248·68	R_2''' (13)
77·961	1	249·91	R_3''' (13)
76·709	0	254·08	R_1''' (14)
76·421	0	255·04	R_2''' (14)
76·080	1	256·18	R_3''' (14)
75·231	2*d*	259·01	R_{23}'' (29)
74·769	0	260·55	R_1''' (15)
74·448	0	261·62	R_2''' (15)
74·172	0	262·54	R_3''' (15)
72·678	1*d*	267·53	R_1''' (16)
72·401	1*d*	268·45	R_2''' (16)
72·112	0	269·41	R_3''' (16)
71·885	0	270·18	
70·745	0	273·98	
70·593	0	274·49	R_1''' (17)
70·282*	2	275·53	R_2''' (17)

* = Band head.

TABLE IV.

λ (I.A.).	Int. (Tube).	ν (Vacuo).	Series.
6191·211*	2	16147·47	P_1 (13), P_1 (12)
91·082	—	147·81	P_1 (14), P_2 (13)
90·727	7*vd*	148·73	P_{23} (14), P_2 (10)
90·592	7	149·09	P_1 (15), P_3 (10)
90·415	6	149·55	P_2 (15), P_2 (9)
90·204	6*d*	150·10	P_1 (16), P_3 (15)
V. Diff.	—	—	P_{23} (16), P_{12} (8)
89·795	3	151·27	P_3 (8) ?
89·575	5	151·84	P_1 (17)
89·382	2	152·29	P_2 (17)
89·243	2	152·60	P_3 (17)
88·932	2*vd*	153·42	P_1 (18)
88·600	2*vd*	154·28	P_{23} (18)
88·272	2*d*	155·14	
88·066	1*c*	155·68	P_1 (19)
87·891	1	156·13	P_2 (19)
87·770	1	156·45	P_3 (19)
87·167	1	158·02	P_1 (20)
86·949	2*c*	158·60	P_2 (20)
86·882	2*c*	158·77	P_3 (20)
86·115	2	160·77	P_1 (21)
85·933	2	161·25	P_2 (21)
85·843	2	161·48	P_3 (21)
84·975	2	163·75	P_1 (22)
84·739	2*c*	164·37	P_2 (22)
84·686	2*c*	164·51	P_3 (22)
83·653	0	167·21	P_1 (23)
83·497	2*c*	167·62	P_2 (23)
83·402	1*c*	167·86	P_3 (23)
82·292	0	170·77	P_1 (24)
82·032	1	171·45	P_{23} (24)
80·747	0	174·81	P_1 (25)
80·521	1	175·40	P_{23} (25)
79·145	1	179·00	P_1 (26)
78·926	1	179·58	P_{23} (26)
77·363	0	183·67	P_1 (27)
77·183	1	184·14	P_{23} (27)
75·481	2	188·60	P_1 (28)
75·281	2	189·13	P_{23} (28)
74·567	0	191·00	
73·693	0	193·29	
73·289	0*d*	194·35	P_{23} (29)
73·025	0	195·04	
72·510	0	196·39	
71·716	1	198·48	
71·432	0	199·22	P_1 (30)
71·204	0	199·82	P_{23} (30)
70·858	1	200·73	
70·348	1	202·07	
69·648	1*d*	203·91	
68·965	0*d*	205·70	
68·471	1	207·00	R_1 (10)
68·019	1*d*	208·19	R_2 (10)
67·455	1	209·67	R_3 (10)
66·069	1	213·31	R_1 (11)

Table IV (continued).

λ (I.A.).	Int. (Tube).	ν (Vacuo).	Series.
6165·639	1	16214·44	R_2 (11)
65·124	1	215·80	R_3 (11)
63·475	2	220·14	R_1 (12)
63·105	2	221·11	R_2 (12)
62·656	2	222·29	R_3 (12)
60·893	1	226·93	R_1 (13)
60·497	2	227·98	R_2 (13)
60·087	2	229·06	R_3 (13)
58·063	1	234·39	R_1 (14)
57·741	1	235·24	R_2 (14)
57·374	1	236·21	R_3 (14)
55·250	2	241·81	R_1 (15)
54·902	2	242·73	R_2 (15)
54·578	2	243·58	R_3 (15)
52·225	1	249·80	R_1 (16)
51·913	1	250·62	R_2 (16)
51·626	1	251·38	R_3 (16)
49·309	1	257·50	R_1 (17)
48·854	1	258·70	R_2 (17)
48·607	1	259·36	R_3 (17)
45·939	1	266·41	R_1 (18)
45·674	1	267·11	R_2 (18)
45·420	1	267·79	R_3 (18)
42·678	0	275·05	R_1 (19)
42·380	1	275·84	R_2 (19)
42·162	1	276·42	R_3 (19)
39·205	0	284·26	R_1 (20)
38·953	0	284·93	R_2 (20)
38·749	0*d*	285·47	R_3 (20)
35·713	0*d*	293·52	R_1 (21)
35·448	0	294·23	R_2 (21)
35·282	0	294·67	R_3 (21)
32·050	0	303·26	R_1 (22)
31·831	0	303·84	R_2 (22)
31·614	0	304·42	R_3 (22)
28·323	0	313·17	R_1 (23)
28·077	0	313·83	R_2 (23)
27·923	0	314·23	R_3 (23)
24·443	0	323·51	R_1 (24)
24·225	0	324·09	R_2 (24)
24·061	0	324·53	R_3 (24)
22·074*	5*d*	329·83	P_2' (14) ?
21·900	10	330·29	P_3' (14) ?, P_1' (15) ?
21·696	10	330·83	P_2' (15) ?
21·526	7*d*	331·29	P_3' (15) ?
21·224	6*d*	332·09	P_1' (16)
20·915	2*c*	332·92	P_3' (16)
20·828	00 ?	333·15	
20·617	3	333·71	P_1' (17)
20·435	3	334·20	P_2' (17)
20·290	3	334·58	P_3' (17)
19·995	4	335·37	P_1' (18)
19·826	3	335·82	P_2' (18)
19·669	3	336·24	P_3' (18)
19·214	6	337·46	P_1' (19)

Table IV (continued).

λ (I.A.).	Int. (Tube).	ν (Vacuo).	Series.
6119·042	2	16337·91	P_2' (19)
18·924	2	338·23	P_3' (19)
18·366	3	339·72	P_1' (20)
18·167	3	340·25	P'_2 (20)
18·047	3	340·57	P_3' (20)
17·369	3	342·38	P_1' (21)
17·171	2*c*	342·91	P_2' (21)
17·086	2*c*	343·14	P_3' (21)
16·289	2	345·27	P_1' (22)
16·061	2*c*	345·88	P_2' (22)
15·993	2*c*	346·06	P_3' (22)
15·064	1*c*	348·54	P_1' (23)
14·892	1*c*	349·00	P_2' (23)
14·774	1*c*	349·32	P_3' (23)
14·532	0	349·97	
14·326	00	350·52	
13·750	1	352·06	P_1' (24)
13·563	1*c*	352·56	P_2' (24)
13·479	1*c*	352·78	P_3' (24)
12·289	2*d*	355·97	P_1' (25)
12·048	3*d*	356·61	P_{23}' (25)
11·184	1*d*	358·93	R_2' (5) ?
10·765	1	360·05	P_1' (26)
10·505	2*d*	360·74	P_{23}' (26)
09·088	2*vd*	364·54	P_1' (27)
08·875	2*vd*	365·11	P_{23}' (27)
08·448	1*vd*	366·25	R_1' (6) ?
07·784	0*d*	368·03	R_2' (6) ?
07·338	1	369·23	P_1' (28)
07·124	2*d*	369·80	P_{23}' (28)
06·793	1	370·69	R_3' (6) ?
06·626	0	371·13	R_1' (7) ?
05·966	1	372·90	R_2' (7) ?
05·426	00	374·35	P_1' (29)
05·244	1	374·84	P_{23}' (29)
05·252	1*c*	374·82	R_3' (7) ?
04·491	1	376·86	R_1' (8)
03·941	1	378·33	R_2' (8)
03·432	00 ?	379·70	P_1' (30)
03·208	4*d*	380·30	P_{23}' (30), R_3' (8)
02·400	2	382·47	R_1' (9)
01·871	2	383·89	R_2' (9)
01·182	4	385·74	R_3' (9)
00·084	2	388·69	R_1' (10)
6099·655	2	389·84	R_2' (10)
99·057	4*d*	391·45	R_3' (10)
98·927	0	391·80	
97·801	2	394·83	R_1' (11)
97·356	3	396·02	R_2' (11)
96·812	3	397·48	R_3' (11)
95·287	3	401·59	R_1' (12)
94·916	3	402·59	R_2' (12)
94·448	3*c*	403·84	R_3' (12)
94·252	2*c*	404·37	
92·801	3	408·28	R_1' (13)

Table IV (continued).

λ (I.A.).	Int. (Tube).	ν (Vacuo).	Series.
6092·418	3	16409·31	R_2' (13)
92·002	3	410·43	R_3' (13)
90·091	4	415·58	R_1' (14)
89·764	4	416·46	R_2' (14)
89·369	4*d*	417·53	R_3' (14)
87·380	4*d*	422·89	R_1' (15)
87·029	4	423·84	R_2' (15)
86·695	4	424·74	R_3' (15)
84·475	3	430·73	R_1' (16)
84·170	3	431·56	R_2' (16)
83·866	3	432·38	R_3' (16)
81·452	3	438·66	R_1' (17)
81·218	4	439·53	R_2' (17)
80·959	4	440·23	R_3' (17)
78·429	3	447·08	R_1' (18)
78·154	3	447·77	R_2' (18)
77·890	3	448·53	R_3' (18)
75·305	3	455·53	R_1' (19)
74·992	3	456·38	R_2' (19)
74·764	3	457·00	R_3' (19)
71·983	2	464·54	R_1' (20)
71·708	2	465·28	R_2' (20)
71·510	2	465·82	R_3' (20)
68·620	1	473·66	R_1' (21)
68·338	2	474·43	R_2' (21)
68·161	2	474·91	R_3' (21)
65·099	2	483·22	R_1' (22)
64·837	2	483·94	R_2' (22)
64·652	2	484·44	R_3' (22)
61·532	1	492·92	R_1' (23)
61·280	1	493·61	R_2' (23)
61·116	1	494·06	R_3' (23)
59·685*	7	497·95	
59·524	3	498·39	
59·329	10*d*	498·82	
59·160	10	499·38	
58·879	6*d*	500·15	
58·642	4	500·79	
58·391	3*vd*	501·48	
58·148	3	502·14	
58·004	3	502·53	
57·834	5	502·99	
57·580	7	503·69	
57·395	7*d*	504·19	
57·107	2	504·97	
56·830	3*vc*	505·73	
56·701	3*vc*	506·08	
56·352	3*d*	507·03	
55·923	4*d*	508·20	
55·373	1	509·70	
55·170	1	510·23	
55·024	1	510·65	
54·677	1	511·60	
54·356	2*d*	512·47	
54·030	3*d*	513·36	

Table IV (continued).

λ (I.A.).	Int. (Tube).	ν (Vacuo).	Series.
6053·806	1	16513·97	
53·657	0	514·38	
53·239	1*d*	515·52	
52·951	0*vd*	516·31	
53·011	1*vd*	518·87	
51·712	3*vd*	519·69	
50·807	0*c*	522·16	
50·657	0*c*	522·57	
50·438	1*c*	523·27	
50·294	1*c*	523·56	
50·079	1	524·15	
49·889	0*c*	524·66	
49·746	0*c*	525·05	
49·595	0	525·46	
49·011	2*c*	527·06	
48·745	0	527·79	
47·702	1	530·64	
47·463	2	531·29	
47·322	0	531·68	
46·321	0	534·41	
46·124	0	534·95	
45·764	5*d*	535·94	
45·336	0	537·11	
44·732	1*d*	538·76	
43·996	3*d*	540·77	
43·096	1	543·24	
42·837	0	543·95	
42·590	0*d*	544·62	
42·097	2*d*	545·97	
41·728	1*d*	546·98	
41·292	0	548·18	
40·727	0	549·73	
40·565	0	550·17	
40·193	3	551·19	
39·378	1	553·42	
39·178	0	553·97	
38·325	2	556·31	
38·030	1	557·12	
37·601	0	558·29	
37·359	2	558·96	
36·879	00	560·28	
36·119	1*d*	562·36	
35·354	0	564·46	
35·196	0	564·90	
34·955	0	565·55	
33·716	0	568·96	
33·551	0	569·41	
33·201	1	570·37	
32·968	1	571·01	
32·119	3*d*	573·34	
31·348	1*d*	575·46	
31·179	00	575·93	
30·857	1	576·81	
30·646	1	577·39	
28·767	3*d*	582·56	

Table IV (continued).

λ (I.A.).	Int. (Tube).	ν (Vacuo).	Series.
6028·317	3*d*	16583·80	
26·141	3	589·78	
25·735	2	590·90	
24·944	2*d*	593·08	
23·339	3	597·50	
23·244	2	597·76	
22·546	2	599·69	
20·564	2	605·15	
20·205	2	606·14	
19·843	2*c*	607·14	
19·270	0	608·72	
17·546	1	613·48	
17·237	2	614·33	
16·942	2	615·15	
14·545	2	621·77	
14·267	00	622·54	
13·954	3	623·40	
13·345	0	625·09	
12·948	0	626·18	
11·374	1	630·54	
11·077	1	631·36	
10·821	1*c*	632·07	
10·663	1	632·50	
10·228	0*d*	633·71	
08·179	2	639·38	
07·866	2	640·25	
07·677	2	640·77	
04·878*	3*c*	648·53	
04·778	7*c*	648·81	P_1 (14) ?
04·612	10	649·26	
04·536	8*c*	649·48	P_1 (15) ?
04·423	6*d* ?	649·79	P_1 (16) ?, P_2 (14) ?
04·289	10	650·16	P_2 (15) ?
04·089	7	650·72	P_1 (17), P_2 (16), P_3 (15)
03·931	3	651·15	P_3 (16)
03·777	7	651·58	P_2 (17)
03·595	1	652·09	P_1 (18), P_3 (17)
03·389	6	652·66	P_2 (18)
03·230	1*c*	653·10	P_1 (19), P_3 (18)
02·976	3*c*	653·80	P_2 (19)
02·845	2*vc*	654·17	P_3 (19)
02·416	1*vc*	655·36	P_2 (20)
02·270	1*vc*	655·76	P_3 (20)
01·888	4	656·82	P_1 (21)
01·661	3	657·45	P_2 (21)
01·487	2*d*	657·93	P_3 (21)
01·097	3	659·01	P_1 (22)
00·914	4*d*	659·52	P_2 (22)
00·745	1	659·99	P_3 (22)
00·154	2	661·63	P_1 (23)
5999·898	2	662·34	P_2 (23)
99·747	2	662·76	P_3 (23)
99·143	1	664·44	P_1 (24)
98·941	1	665·00	P_2 (24)
98·815	1	665·35	P_3 (24)

Table IV (continued).

λ (I.A.).	Int. (Tube).	ν (Vacuo).	Series.
5997·986	1	16667·66	P_1 (25)
97·804	1	668·16	P_2 (25)
97·581	2	668·78	P_3 (25)
97·336	1*d*	669·46	
96·800	1	670·95	P_1 (26)
96·603	1	671·50	P_2 (26)
96·484	1	671·83	P_3 (26)
95·969	0	673·26	
95·409	1	674·82	P_1 (27)
95·091	3*d*	675·70	P_{23} (27)
94·234	1	678·09	
94·006	1	678·72	
93·772	3*d*	679·37	
92·445	0	683·07	
92·130	1*vd*	683·95	
91·570	1*d*	685·50	
91·154	1	686·66	
90·935	0	687·27	
90·082	3*vd*	689·65	
89·447	1	691·42	
88·800	1*d*	693·22	
88·498	2	694·06	
88·147	0	695·04	
87·566	1	696·66	
87·192	0*c*	697·70	
86·747	2	698·95	
86·253	2	700·32	R_1 (9)
85·647	2	702·11	R_2 (9)
84·939	3	703·99	R_3 (9)
84·092	2	706·36	R_1 (10)
83·640	2	707·62	R_2 (10)
83·280	1*d*	708·72	
82·975	2	709·47	R_3 (10)
82·003	2	712·19	R_1 (11)
81·497	2	713·60	R_2 (11)
81·338	0	714·05	
80·914	4*d*	715·23	R_3 (11)
79·677	2	718·69	R_1 (12)
79·264	3	719·84	R_2 (12)
78·758	3	721·26	R_3 (12)
77·388	2	725·09	R_1 (13)
76·942	3	726·34	R_2 (13)
76·485	3	727·62	R_3 (13)
74·900	3	732·06	R_1 (14)
74·540	4	733·06	R_2 (14)
74·130	4	734·21	R_3 (14)
72·406	4	739·04	R_1 (15)
72·005	4	740·17	R_2 (15)
71·628	4*c*	741·23	R_3 (15)
69·747	3	746·50	R_1 (16)
69·413	3	747·44	R_2 (16)
69·077	3	748·38	R_3 (16)
67·058	3	754·05	R_1 (17)
66·707	3	755·03	R_2 (17)
66·395	3	755·91	R_3 (17)

Table IV (continued).

λ (I.A.).	Int. (Tube).	ν (Vacuo).	Series.
5964·228	3	16762·01	R_1 (18)
63·923	3	762·85	R_2 (18)
63·644	3	763·64	R_3 (18)
61·350	3	770·09	R_1 (19)
60·996	3	771·09	R_2 (19)
60·757	3	771·76	R_3 (19)
58·707*	8*c*	777·53	
58·440	4*c*	778·28	
58·330	10	778·59	R_1 (20)
58·112	2*vc*	779·20	
58·043	4*c*	779·40	R_2 (20)
57·833	10*d*	779·99	R_3 (20)
57·597	3	780·65	
57·270	2	781·58	
57·091	2	782·08	
56·886	2	782·66	
56·650	2	783·32	
56·363	3*vd*	784·13	
56·019	2*d*	785·10	
55·611	1*vd*	786·25	
55·300	2	787·12	
55·231	1	787·32	
54·941	0	788·14	R_1 (21) ?
54·680	3*vd*	788·87	R_2 (21) ?
54·488	2	789·42	R_3 (21) ?
53·803	0	791·35	
53·672	0	791·72	
53·410	0	792·45	
52·969	1*d*	793·70	
52·633	0	794·65	
52·063	0	796·27	
51·783	2*c*	797·06	R_1 (22)
51·589	2	797·60	R_2 (22)
51·371	2	798·21	R_3 (22)
50·421	2*d*	800·89	
49·262	0*d*	804·11	
49·006	1*c*	804·89	
48·806	1*c*	805·45	
48·497	1	806·32	R_1 (23)
48·292	0	806·90	R_2 (23)
47·605	1*d*	808·84	R_3 (23)
46·818	0	811·07	
45·466	1	814·89	
45·199	2*d*	815·65	
44·119	0*d*	818·70	
43·814	0*d*	819·56	
43·237	1*d*	821·20	
42·932	2*d*	822·06	
42·565	0	823·10	
42·436	0	823·47	
41·985	0*c*	824·74	
41·841	0*c*	825·15	
41·680	0*c*	825·61	
41·529	1*c*	826·03	
41·131	1	827·16	

Table IV (continued).

λ (I.A.).	Int. (Tube).	ν (Vacuo).	Series.
5940·464	0*vd*	16829·05	
39·843	1*vd*	830·81	
39·197	1	832·64	
38·438	2*c*	834·79	
38·205	2*c*	835·45	
37·390	0	837·76	
36·425	0*d*	840·50	
35·951	0	841·84	
35·425	0	843·34	
34·779	1	845·17	
34·530	1	845·88	
34·120	1	847·04	
33·628	0	848·44	
32·868	0	850·60	
32·063	0	852·88	
31·332	0	854·96	
31·114	0*d*	855·58	
30·784	0	856·52	
29·617	1	859·83	
29·171	1	861·10	
28·638	1	862·62	
27·301	1*vd*	866·42	
27·019	2*vd*	867·22	
26·494	0*d*	868·72	
24·702	1	873·82	
24·337	0	874·86	
23·879	2	876·17	
23·679	0	876·74	
23·417*	5	877·48	

Notes.

* = Band head.

In the λ 6005 band the three accents in the series notation have been omitted as no possibility of confusion exists.

TABLE V.

Wave-length of Head.	Intensity.	Wave Number in Vacuo.
4382·483	2	22811·73
4371·432	4	22869·40
4365·165	5	22902·25

TABLE VI.

Wave-length of Head.	Head Intensity.	Wave-number in Vacuo.
6671·31	3	14971·96
6599·25	0	15149·06
6533·68	0	15301·09
6480·51	2	15426·63
6442·35	4	15518·01
6424·09	2	15562·12

Note.—The range of error is large, possibly as much as 0·03, owing to the difficulty of identifying the last line of the head which is often very faint.

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DESCRIPTION OF PLATE 4.

(1) Swan bands as seen under low dispersion. The CH band at λ 4315 is also present. Enlarged three times. New bands marked.

(2) High dispersion photograph of the λ 4737 group under arc conditions. The perturbation illustrated in fig. 2 is clearly visible.

(3) Same as (2), but under tube conditions. The characteristic low temperature conditions will be noted. The P branch can just be distinguished as doublets in (2) and as triplets in (3).

(4) The λ 5165 group under arc conditions. The perturbation at P (49) is marked; that at R (48) is just off the plate.

(5) Same as (4), but under tube conditions.

(6) A photograph of the (0, 0) band of the Second Positive Nitrogen system for comparison with the above. The remarkable similarity will be observed. The R branch triplets narrowing away from the origin are very conspicuous.

(7) The λ 5635 and λ 5585 heads (under tube conditions) magnified about three times by enlargement. The original dispersion was about 1·3 Å.U. per millimetre.

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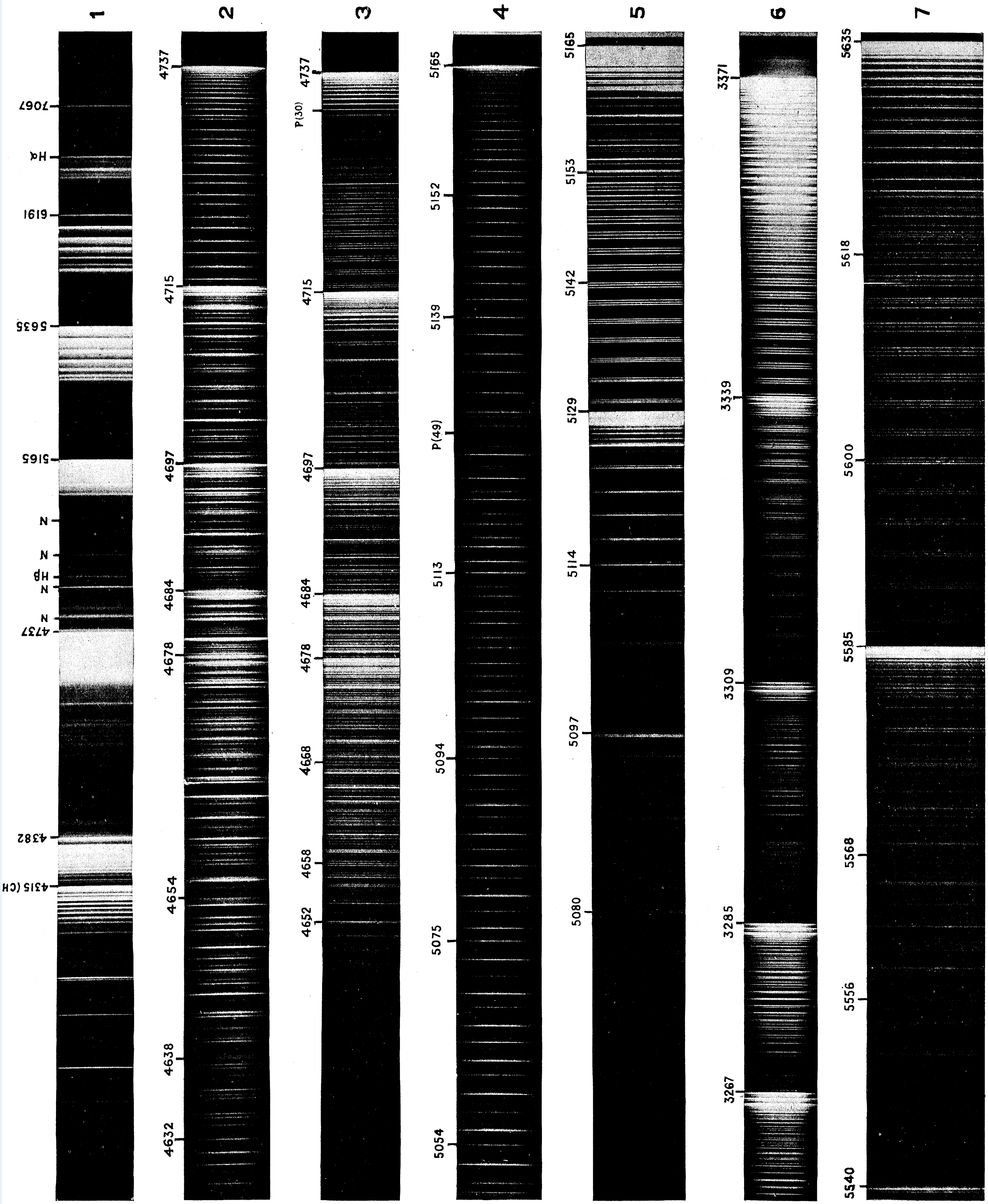

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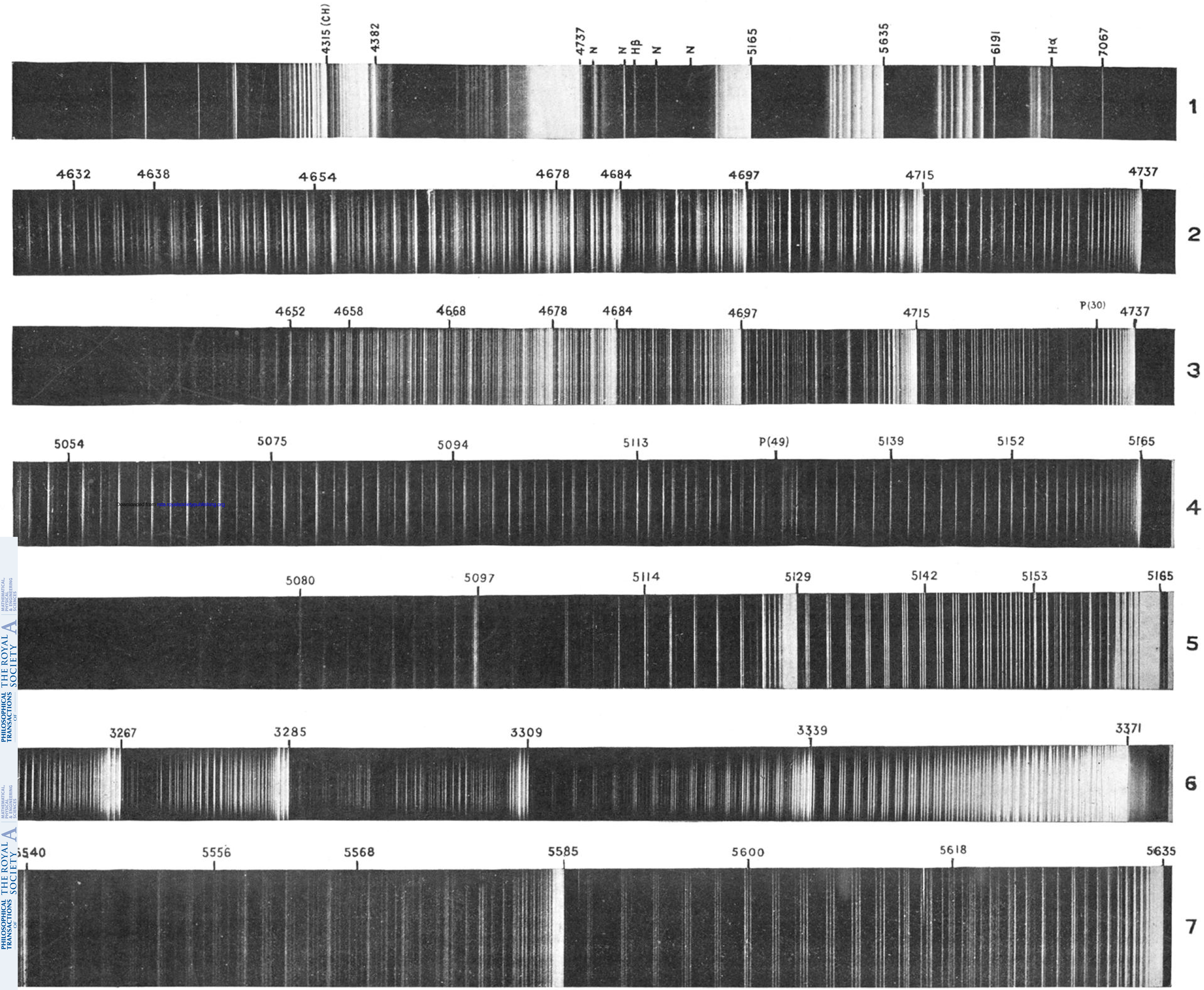
4315 (CH)
4382
4737
N
N
Hβ
N
N
5165
5635
6191
Hα
7067
1
4632
4638
4654
4678
4684
4697
4715
4737
2
4652
4658
4668
4678
4684
4697
4715
P(30)
4737
3
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